Pittsburgh Steel

OIL COUNTRY
LINE AND STANDARD
PIPE

PITTSBURGH STEEL CO.
PITTSBURGH, PA.

Pittsburgh Steel

OIL COUNTRY TUBULAR GOODS
LINE PIPE AND STANDARD PIPE
CATALOG

P

Catalog No. 320L

Book No. P -17

May 15, 1944

PITTSBURGH STEEL COMPANY
Pittsburgh, Pa.

BRANCH OFFICES
NEW YORK • PITTSBURGH • CLEVELAND • DETROIT
CHICAGO • TULSA • HOUSTON • LOS ANGELES

Pittsburgh Steel

OIL COUNTRY TUBULAR GOODS
LINE PIPE AND STANDARD PIPE
CATALOG

INDEX TO CATALOG SECTIONS

(*General Index in Back of Book*)

SECTION	SUBJECT	PAGES
G	The Manufacture of Iron and Steel	G 4 — G 19
	The Manufacture of Steel Pipe and Tubing	G 20 — G 36
P	Oil Country Tubular Goods, Line Pipe, and Standard Pipe	P 1 — P 55
	Index	P 56
D	General Data	D 1 — D240
	Index	D236 — D240

NOTE: The Pittsburgh Steel technical catalogs follow the pattern of this one, each consisting of (1) Catalog Section G, (2) Catalog Section for the product group concerned (in this case Section P, Oil Country Tubular Goods, Line Pipe, and Standard Pipe), and (3) Catalog Section D. Other product group sections are: B—Pressure Tubes; M—Mechanical Tubing; S—Stainless Steel Products; W—Steel and Wire Products. If interested in adding one of these other sections to this catalog, communicate with us.

ONE COMPANY • ONE ORGANIZATION
ONE RESPONSIBILITY

As a completely integrated steel manufacturer, Pittsburgh Steel Company controls every step in the making of its products from raw materials to final inspections. Its plants, the by-product coke plant, steel and wire products plant, and the nearby tubular products plant are operated practically as a single unit.

"Pittsburgh" Steel Products are produced by one organization at, in effect, one manufacturing location. It is this concentrated manufacturing and responsibility which account for the consistently uniform quality maintained not only from item to item but also from order to order and from year to year.

Pittsburgh
Trade Name for Pittsburgh Steel Company Products
A Great Name in Steel

PIG IRON   INGOTS   BLOOMS   BILLETS   SHELL STEEL

WIRE RODS   MANUFACTURERS' WIRES
WIRE REINFORCEMENT   STEEL STRAND   FENCES
HIGHWAY GUARD   STEELTEX BUILDING PRODUCTS

SEAMLESS STEEL TUBES
MECHANICAL TUBES   PRESSURE TUBES
OIL WELL CASING, OIL WELL TUBING AND DRILL PIPE
TUBULAR RAILWAY AXLES
WELDED TUBES
PRESSURE TUBES   MECHANICAL TUBES

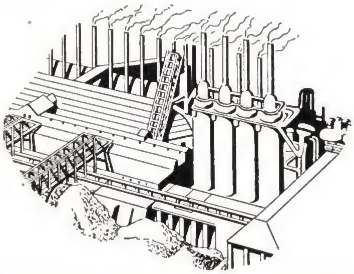
ALLOY AND STAINLESS STEEL
BARS   WIRE   SEAMLESS STEEL TUBES AND PIPE

COAL BY-PRODUCTS
FURNACE COKE   RANGE COKE   BREEZE COKE
CRUDE TAR   PITCH   TAR ACID OILS
AMMONIUM SULPHATE   CRUDE PYRIDINE   LIGHT OIL
SODIUM PHENOLATE   MOTOR BENZOL   TOLUOL-XYLOL
LIGHT AND HEAVY INTERMEDIATE SOLVENTS

The "cast" from a blast furnace consists of 150 to 300 tons of molten iron.

Ore bins at blast furnaces contain selected grades of ore, also coke and limestone.

THE MANUFACTURE OF IRON AND STEEL

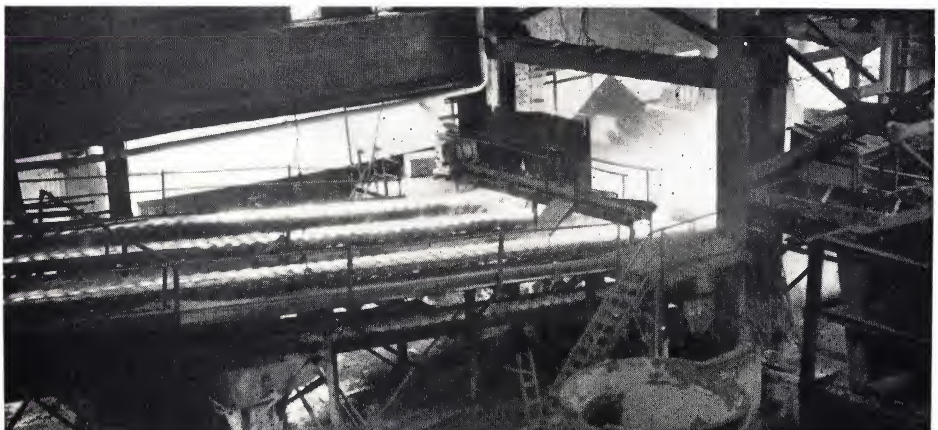


Taking a brief glance at the steelmaking processes, it is interesting to note that more than six tons of raw materials such as iron ore, coke, limestone, etc., are charged into the furnaces for the production of one ton of steel. Iron ore comes chiefly from Minnesota and Michigan. Coal, coming largely from the great Appalachian bituminous fields is converted into steelmaking coke. Limestone is quarried mostly in Pennsylvania, Ohio, and Maryland. Dolomite, manganese, copper, aluminum, silicon, and many other materials are used.

The necessary materials having been assembled, the first step in steel manufacture is the production of pig iron. Pig iron is made in 90- to 100-foot high blast furnaces into which are charged measured quantities of iron ore, coke (for fuel) and limestone (to separate the impurities from the iron). These materials are melted down under the intense heat of a pre-heated, oxygen-fed forced blast fire. Wastes and impurities from the ore combine to form a slag which separates from the molten iron, much as cream separates from milk, and is drawn from the furnace periodically. The remaining molten metal is then tapped out at the bottom of the furnace into large fire-brick-lined receptacles called "ladles." The time required for completing each blast furnace charge is about five hours. Our capacity of blast furnace production is in excess of 2500 tons of pig iron each day.

If the molten pig iron is to be made promptly into steel it is taken in the ladles to a "hot metal mixer," or reservoir, where it is kept hot and drawn upon as required for charging into the steelmaking furnaces. On the other hand, if the pig iron is to be stored for future use it is cast into small molds — or "pigs"— and cooled. These pigs weigh roughly 135 pounds each.

Iron from the blast furnace when not scheduled for immediate use is cast into "pigs," in which form it is technically "pig iron."



THE MANUFACTURE OF STEEL

The next step is the further refining of pig iron, which in its crude state contains many impurities and an excess of such substances as carbon, silicon, manganese, phosphorus, and sulphur. Also it lacks the toughness, ductility, and tensile strength that come from repeated rolling, working, and control of chemical content necessary to produce finished steel products.

In American steelmaking practice there are two chief methods of converting large tonnages of iron into steel — the Acid Bessemer process and the Basic Open Hearth process. Acid steel is steel that has been refined by oxidation alone, which removes carbon, silicon, and manganese from the iron. Basic steel is steel that has been purified by oxidation plus the addition of a strong base, usually lime, to remove also phosphorus and sulphur. Although either acid or basic steel can be produced both by Bessemer and Open Hearth processes, the composition of iron ores available in the United States causes most American steels to be produced either by the Acid Bessemer or by the Basic Open Hearth process.

Stainless Steels and other high alloy steels are produced in electric furnaces. Pittsburgh Steel Company employs the Basic Open Hearth method for producing carbon and low alloy steels, and uses electric furnace steels in the higher alloy ranges. Under the pressure and emergencies of wartime needs

The charging floor for the battery of twelve open hearth furnaces.

we have learned to make successfully, in open hearth furnaces, many alloy steels which were formerly produced only in electric furnaces.

BASIC OPEN HEARTH STEEL

The Open Hearth furnace is a large rectangular bowl of approximately 140 tons metal capacity, completely enclosed by brick walls of highly heat-resistant refractory brick. In making steel the pre-heated, dolomite lined bottom of this furnace is first covered with about 30,000 pounds of limestone, which in turn is heated to a temperature of more than 3000° F.

Selected scrap iron and steel, which is metal previously refined, makes up about one-half of the furnace charge.

Now comes the charging into the furnace of a fixed amount of selected scrap steel, which is subjected to a full heat for about two hours, or until it is melted down to thick liquid ready for admixture with hot iron from the blast furnace. Molten iron — about 70 tons of it — is then charged into the furnace where it mixes with the partly melted steel already there.

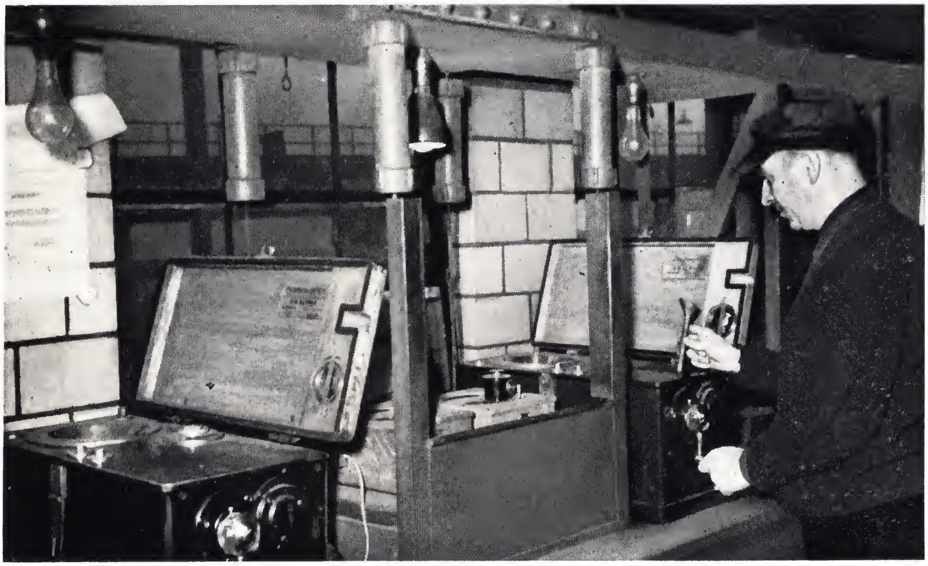
The heating in an open hearth furnace is done by combustion of pre-heated gas and pre-heated air forced into and through the furnace alternately from one side, then from the other. The residual heat in the burned gases leaving the furnace is employed, by this alternating process, for pre-heating the gas and air next entering the furnace.

Molten iron from the hot metal mixer makes up the balance of the furnace charge.

With the charging completed the mass of metal inside the furnace undergoes a "lime boil" period for several hours, during which the limestone from the bottom of the furnace, calcined by the heat, moves slowly upward through

During the steelmaking period a number of test samples are taken from the furnace for laboratory analysis.

and to the surface of the molten metal, purifying as it goes. The calcined lime and impurities from the iron combine to form slag which floats on the surface.



Here, in the open hearth control laboratory, a sample is to be given a Carbometer test.

Following the lime-boil period the heat is continued to the "working period," during which the greatest skill and experience are necessary to maintain the

The "pit side" of the battery of open hearth furnaces shows 140 ton "ladles" ready to receive completed heats of steel from the furnaces.

Tapping an open hearth furnace. At about 2900° F. the white-hot metal flows quickly into the huge ladle.

proper temperatures and to control all of the other factors in accordance with the requirements of each individual heat. Throughout this period many samples of the metal are taken from the furnace for expert examination and metallurgical laboratory analysis to make possible the necessary control of the "heat." It is also during the "working period" that materials such as copper, manganese, nickel, etc., are added when desired. The period of time required for completing a "heat" of 140 tons of Basic Open Hearth steel is approximately 11 hours. At all times the production of steel in our furnaces and mills is under the complete control of our metallurgical laboratory.

TEEMING INGOTS

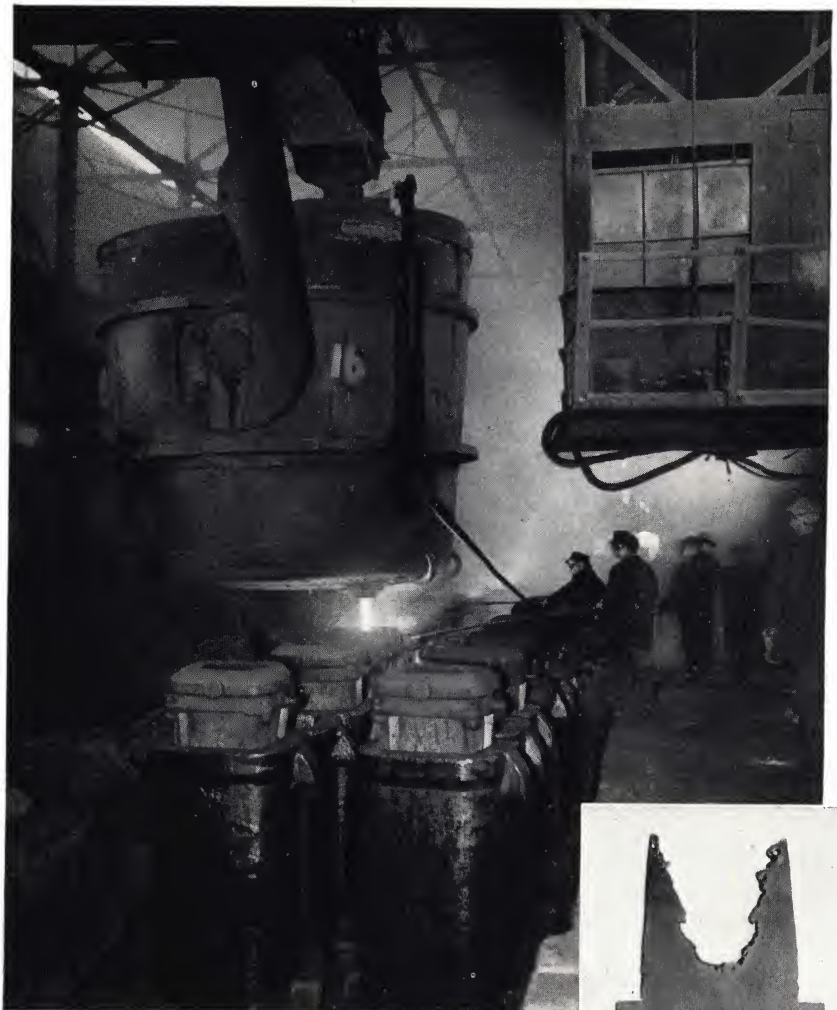
When the molten steel is tapped from the Open Hearth furnace it is received in a large fire-brick-lined ladle from which it is immediately cast into individual ingot molds producing ingots of approximately 4 tons, usually rectangular in cross section, but in some cases and for special purposes round in cross section.

Depending upon the character of steel being poured and the purpose for which it is destined, the ingots are either "top-poured"— that is, each ingot mold is filled directly from the ladle — or "bottom-cast," by which method the steel is poured into a central piping riser, and the ingot molds filled from the bottom.

We employ different types of molds and teeming practice for top-poured ingots. Rimmed steel is teemed into plain rectangular molds; killed steel is teemed into "hot-top" molds, impurities and piping concentrating largely in the hot-top portion for convenient cropping back of the blooming mill; capped steel is teemed into "bottle-top" shaped molds which are closed with lids or caps immediately after each mold is filled. See the accompanying illustrations and legends for further description of the molds and respective general groups of steel produced.

Rimmed steel has a heavy skin or "rim" of dense steel somewhat purer and more compact than the core.

Rimmed ingots are teemed into plain molds.



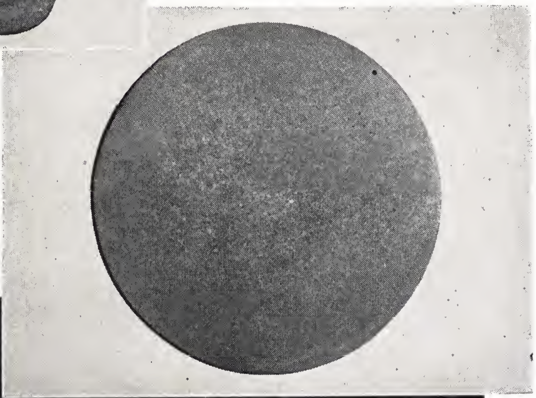
Teeming ingots in hot-top molds; piping and impurities are largely confined to the "hot-top," involving minimum loss of steel in subsequent cropping.

The steel is allowed to remain in the ingot molds for a predetermined time, set from a metallurgical standpoint, after which the molds are stripped from the ingots, or ingots stripped from the molds in the case of large-end-up types, and the ingots are removed to the "soaking pits."

This actual longitudinal "slice" from a hot-top ingot illustrates the hot-top characteristics.

Characteristics of capped steel are a thin skin or "rim," and a core approaching that of killed steel.

In killed steel a deoxidizing agent is employed to prevent gas evolution during solidification, producing a relatively homogeneous steel section without any definite rim.



Teeming capped ingots. Rimming action is stopped short by capping.

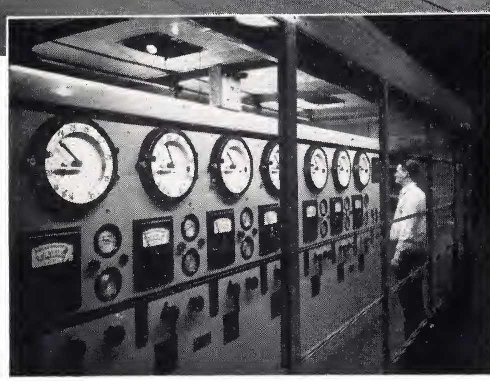
Round ingots for pipe manufacture are bottom cast, the molds literally filled from the bottom.

When ingots have solidified they shrink from the molds, and molds are stripped from the ingots, or vice-versa.

ROLLING STEEL

Omitting many details but touching upon some of the most important essential factors in the production of uniformly high quality steel, we now come to the point where, instead of by melting and pouring, the metal is carried further in preparation and refinement through controlled lower temperatures and rolling.

A battery of modern surface-type soaking pits. Note uniform color of ingot, indicating uniform temperature throughout.



Control room for above battery of soaking pits.

Soaking ingots: Before an ingot can be successfully rolled, its interior and exterior temperatures must be approximately the same overall, for temperature inequalities in the ingot would cause trouble in rolling, with

consequent imperfections in the finished steel. Each ingot is therefore taken immediately after stripping to the "soaking pits." These soaking pits, located in the same building with the blooming mill, are comparatively small gas-fired pit furnaces, each accommodating about 50 tons of ingots. Here the ingots, standing on end, are allowed to "soak" in heat of from about 2200° to 2400°F., until they reach that temperature uniformly.

Repeated passes through the blooming mill reduce the 22" x 24" ingots to blooms approximately 7" x 7".

Blooming: The uniformly heated ingot is taken from the soaking pit directly to the "blooming" mill. Here it is rolled forward and backward through a series of "passes," each successively smaller than the preceding one, until the ingot — which was about 6 feet long and 22 x 24 inches in its other dimensions — has been reduced to a "bloom" about 40 feet long by 7⅝ inches square. Many alloy blooms are cooled in accordance with pre-determined metallurgical standards. The cooling time may run from 50 to 200 hours. This slow cooling removes traces of hydrogen and evidence of flaking.

The 7" x 7" blooms proceed through a number of roll passes in this billet mill emerging as 4" x 4" billets, 1¾" x 1¾" bars, or tube rounds of various diameters.

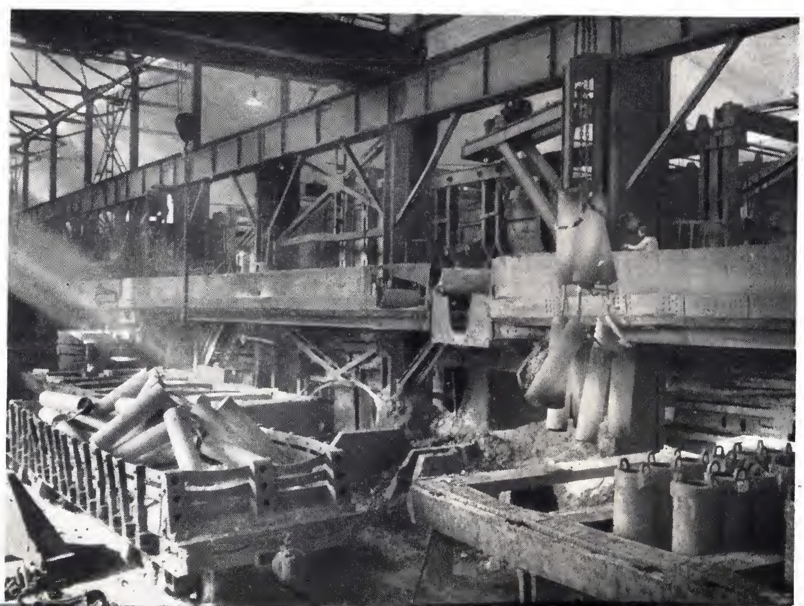
After the rough ends are cropped from the bloom it proceeds directly to the billet mill, where by further rolling it is reduced to a billet about 4 inches square in cross section when destined for finished products other than seamless tubes, or rolled into a round billet from 2 inches to 6½ inches in diameter when destined to be finished into Seamless Steel Tubing. Our equipment is adequate to take care of the controlled cooling of billets for large tonnages of various alloy steels.

Billets to be promptly cooled are either air cooled or water cooled on these modern cooling tables.

Slow cooling of billets is conducted in these large capacity slow-cooling pits.

This covers in a very brief way the production of what is termed "semi-finished" steel. As indicated, the metal ordinarily is kept hot throughout these processes. Now in billet form the steel is allowed to cool, is properly marked for identification and either stored for later use or taken to the finishing mills to be manufactured into some finished steel product.

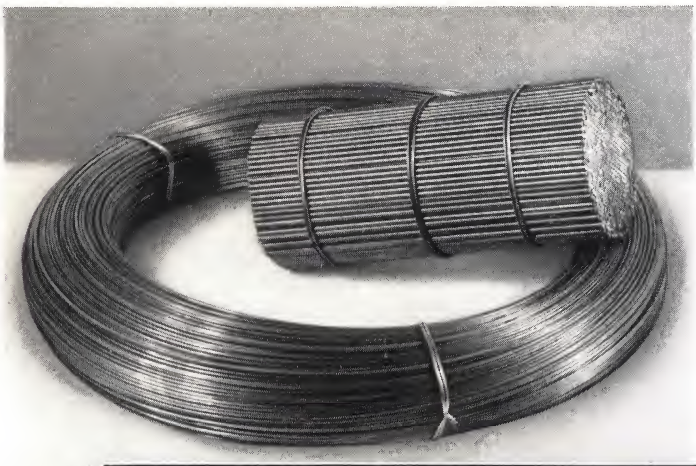
Stripping and loading of round ingots which move directly to the Pilger pipe and tube mill discussed later in this section.



FINISHED "PITTSBURGH" STEEL PRODUCTS

Where the manufacturing processes are carried beyond the "semifinished" stages discussed on the preceding pages, the products will here be referred to as "finished" products. The term, however, should not be taken too literally. From our standpoint, a coil of wire is a "finished" product; but from the buyer's standpoint it may be "raw material" out of which he fabricates springs, welding electrodes, screws, reinforcing mesh, etc., which "finished" products in turn may be another manufacturer's "raw materials."

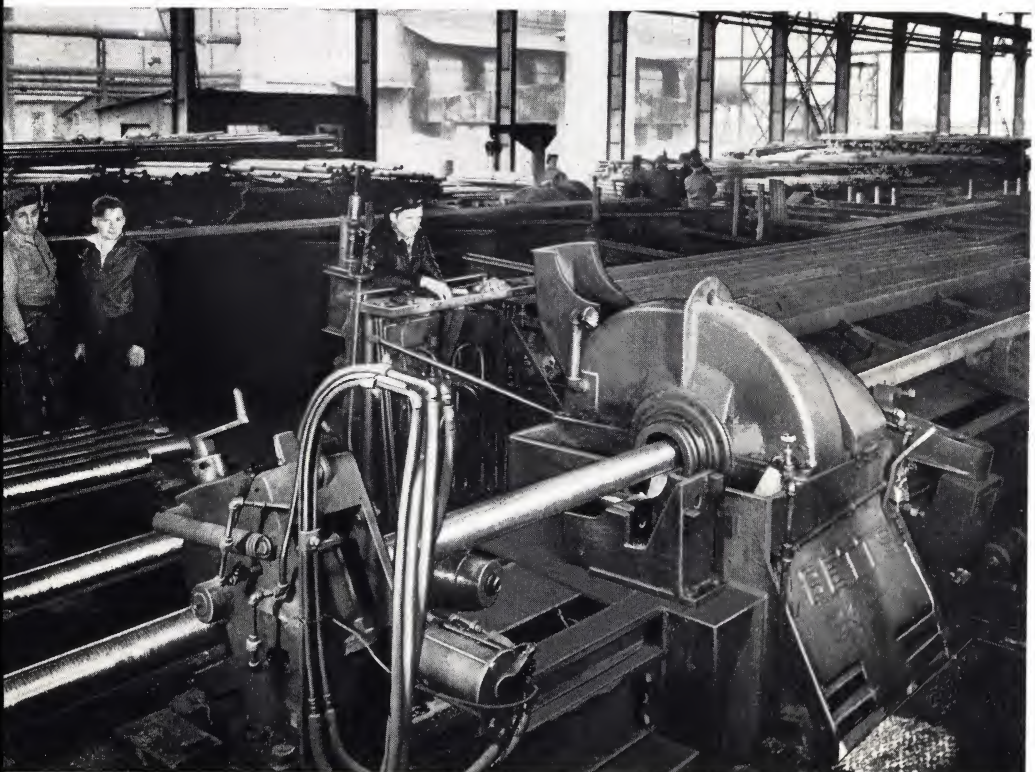
On the following pages is a brief general discussion of the manufacture of pipe and tubing. In their respective catalog sections will be found certain further information pertinent to Pipe and Oil Country Tubular Goods, Pressure Tubes, Mechanical Tubing; also Stainless Steel Wire, Pipe, and Tubing Products; and Steel and Wire Products.



Finished products from our standpoint include wire in coils or straightened and cut, reinforcing fabric, highway guard, Steeltex lath, fences, nails, etc.; also many straight and formed steel tubular products.

THE MANUFACTURE OF STEEL PIPE AND TUBING

The semifinished steel used for the manufacture of pipe and tubing is in the form of round ingots, round billets (tube rounds), and skelp (for welded tubes). We are chiefly concerned here with the manufacture of seamless steel tubes made from round billets.



Round billets for tube manufacture (tube rounds) are peeled to remove surface imperfections.

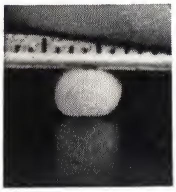
PIERCING BILLETS

Seamless steel tubes are made at our Allenport, Pa., plant by the piercing process known as Mannesman Roll Piercing. There are some modifications in details of the process even among the piercing mills in our plant, but basically the process is as indicated in the accompanying diagram.

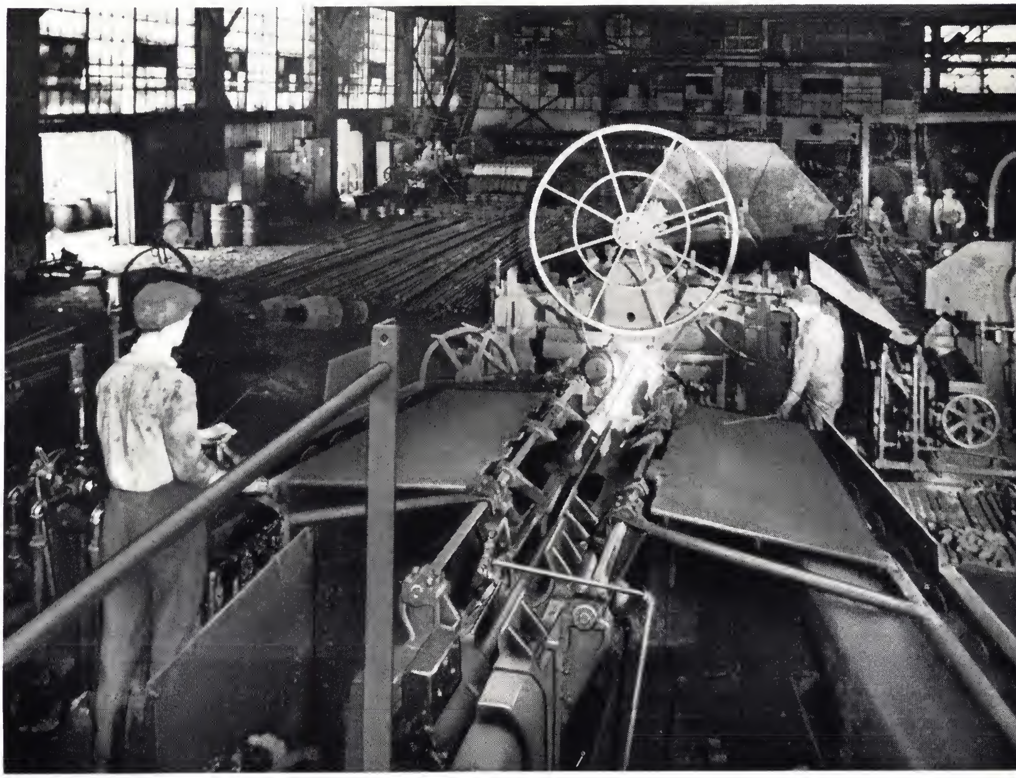
The principles employed are both diagonal rolling and piercing. The two heavy, barrel shaped rolls taper at an angle of 5 to 10° toward each end from a flat central portion about 1 inch wide. These rolls are placed in their housings side by side, their axes slightly askew and inclined in opposite directions, but corresponding at their centers.

The billet to be pierced is uniformly heated and conveyed to a trough on the entry side of the rolls. Here it is forced into the opening between the rolls. In this opening space is a pointed mandrel or piercing point, held in place by a water-cooled rod from the delivery side of the rolls.

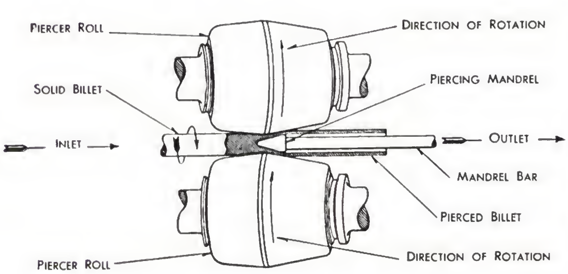
The rolls revolve rapidly, advancing the billet and compressing it into an oval shape (as illustrated) at the narrowest point between the rolls. This tends

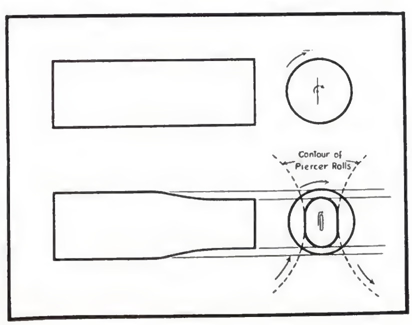


to separate the fibres of steel at the center of the billet and form an opening or tube even without the piercing mandrel. Coincident with this natural tendency of the steel to open up at the center, the piercing mandrel forces the opening in the billet to assume a round shape with a comparatively smooth surface. It emerges from the piercing mill an unfinished, thick-walled tube, ready for further rolling and finishing operations.



Mannesman piercing of tube rounds into a seamless hollow billet or crude tube.



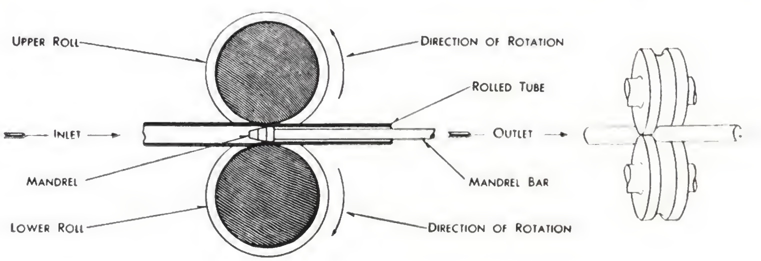


ROLLING SEAMLESS TUBES

It is obvious that the operation of piercing solid steel billets is a severe test of their soundness. Any undetected imperfections in the solid blanks are almost sure to come to light during piercing; at the same time sound steel is strengthened and refined by the rolling as it is being worked under closely determined temperatures.

The unfinished tube from the piercing is refined in structure, dimensions, and finish in the rolling mill.

Semiautomatic Mills: Upon leaving the Mannesman piercer, as previously described, the tube blanks go directly to the rolling mill which consists of two long rolls, one above the other in the stand. Each of these rolls has a series of rolling grooves around its face, each groove progressively smaller than the preceding one. As the rolls are adjusted properly the grooves in both conjoin to make a series of approximately round "passes" through



which the hot tube blank will be rolled successively until it reaches approximately the length, diameter, and wall thickness of the required finished tube. Supported by a long rod at the rear of the mill — as at the piercing mill — is a mandrel or plug over which the tube will be rolled through each pass.

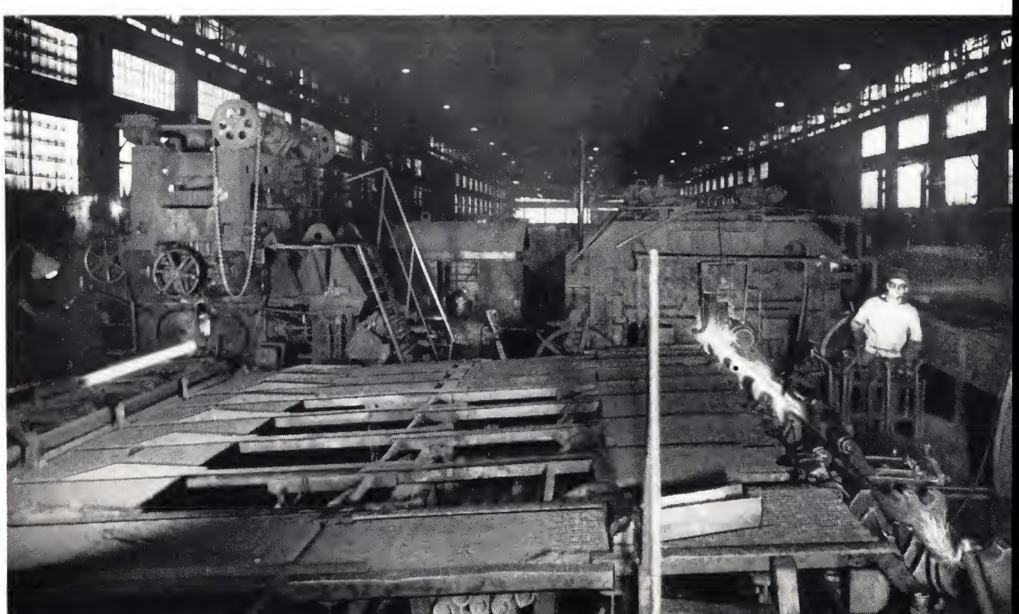
In rolling, one end of the almost white-hot pierced billet, or tube blank, is introduced into the first and largest of the rolling mill passes. When the rolls seize it and force it through the pass the tube is elongated as the extremely thick walls are rolled down to more nearly normal size over the mandrel. Returning automatically from the rear of the mill the tube is rotated 90° and introduced into the second pass, which furthers the action of reducing the outside diameter and wall thickness while lengthening the tube proportionately. The tube receives two or more successive rollings in the same way until it reaches proper size.

Elongator Mill: This mill group, like the Semiautomatic Mill, consists of piercing and rolling equipment. The piercing is essentially a repetition of the Mannesman principle previously described, except that two revolving disc rolls, in addition to the heavy barrel shaped rolls, bear upon the steel at the moment of piercing. These disc rolls have guiding and elongating effect which results in more concentricity in the tube walls.

The pierced tube blanks go directly from this piercing mill to the Elongator rolling mill. This mill has in effect four adjustable rolls — two parallel rolls inclined on their axes, and two disc rolls similar to those used in the accompanying piercing mill. The parallel or working rolls are mounted side by side in the stand; the disc rolls are mounted one above the other and between the working rolls in such a way that the opening pass between the four rolling faces corresponds to the size and shape of the finished tube to be made.

When it comes from the piercing mill the hot pierced billet is transferred to a rack beside the Elongator rolls, where a long, round, smooth mandrel

Improved piercing and rolling processes are incorporated in this elongator mill combination unit.

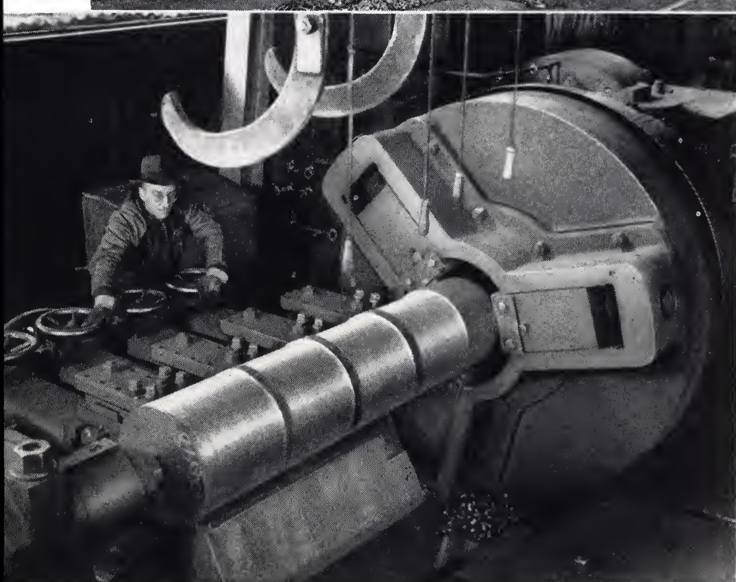


bar is immediately inserted into it. The blank with its mandrel bar is then introduced into the Elongator rolls, where, as the tube is rolled, its inside walls are smoothed over the round mandrel bar, the wall thickness being reduced uniformly, and the exterior smoothly finished. Against the disc, the rolls have an elongating effect ahead of the working roll action which contributes to wall concentricity.

This Elongator mill group produces hot rolled tubes of smaller diameter and lighter walls than are practicable in the other mills. Its further advantages are the remarkably concentric walls and the smooth inside and outside finish it gives the tubes without cold drawing.

Pilger Mill: The Pilger process is employed to make pipe and tubes of larger diameters for such purposes as oil country tubular goods, boiler headers and tubular railway axles.

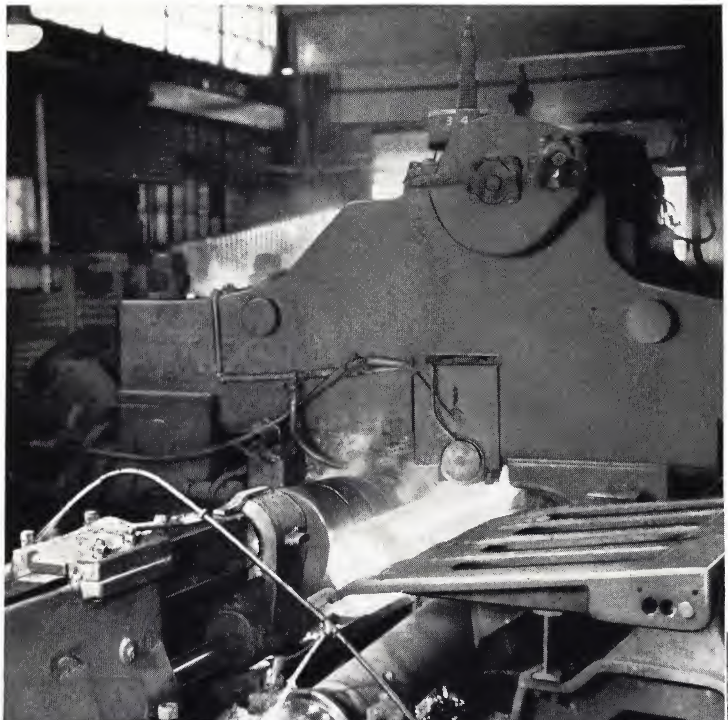
Round ingots, adequately identified, are here awaiting Pilger mill production.



Round ingots are peeled to remove scale and other surface imperfections.

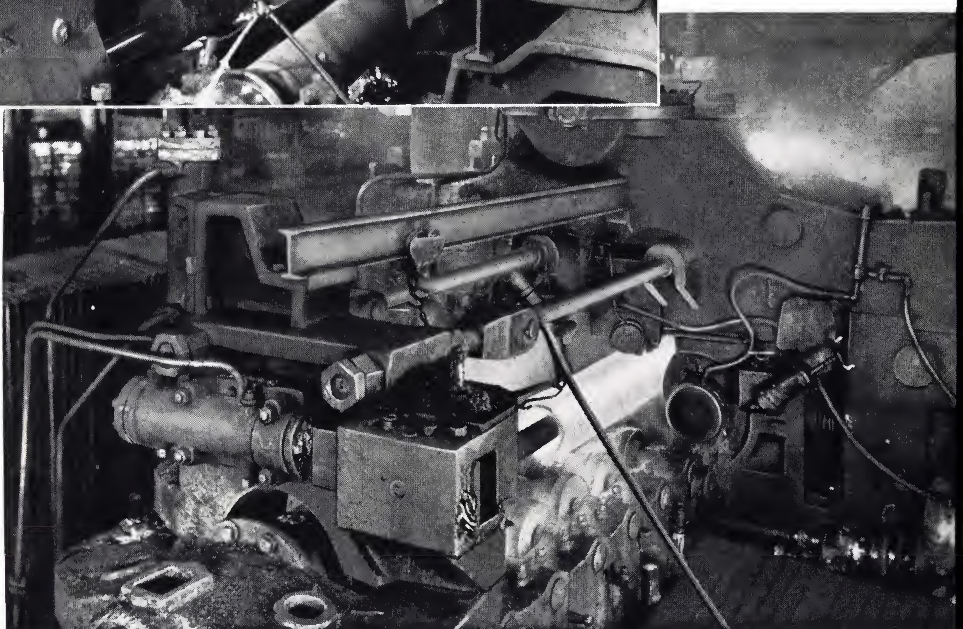
The piercing of the solid steel blank is the same Mannesman process earlier described. Here, however, the solid blanks are large round ingots, surface peeled to eliminate imperfections. The piercer is proportionately large to handle the larger blanks. After this piercing the very heavy walled tubular

"billet" is reheated and conveyed to a second large Mannesman piercing mill where using a larger piercing mandrel, it is given a second "piercing," so-called because of the similarity in mill and action to the initial piercing. The effect of the second piercing is to further enlarge the hole, compress the walls to smaller thickness and elongate the tube blank. The hole in the blank is now thoroughly cleaned out with an air blast before it goes to the Pilger rolling mill.

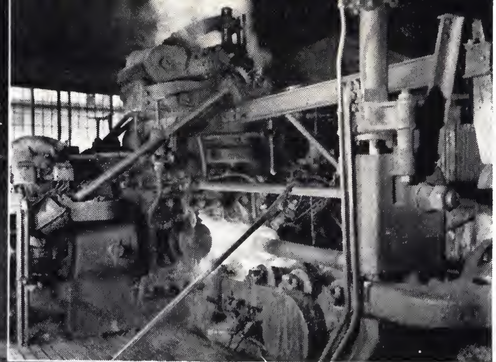


Uniformly heated round ingot enters first piercing unit.

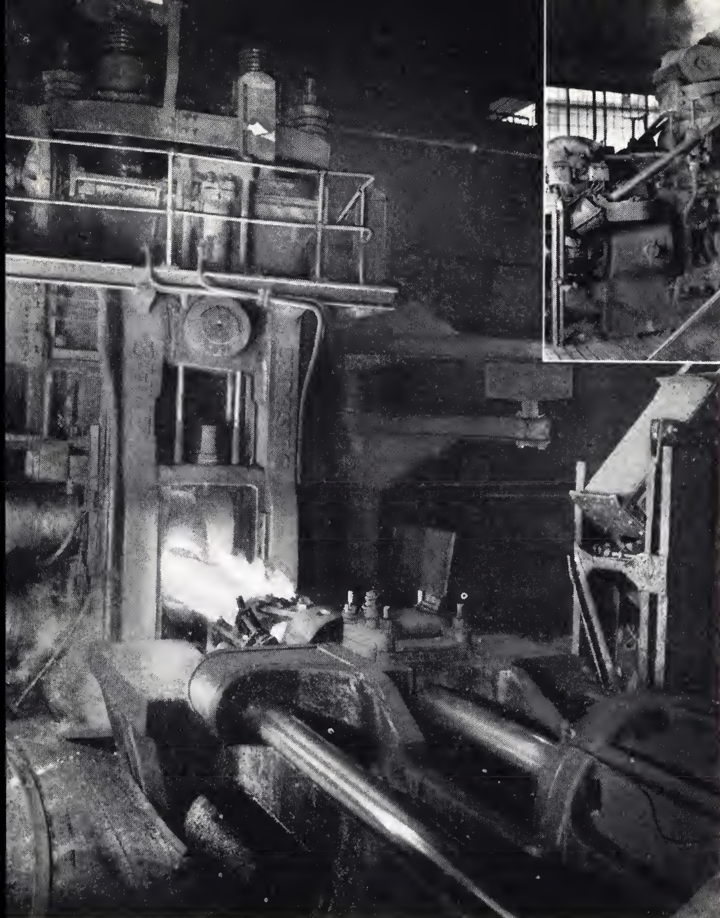
Below: Pierced ingot emerges from first piercer as a heavy walled hollow billet.



Two sets of Pilger rolling mills take the output of the Pilger group piercing mills. The Pilger rolls are placed one above the other in the mill stand with

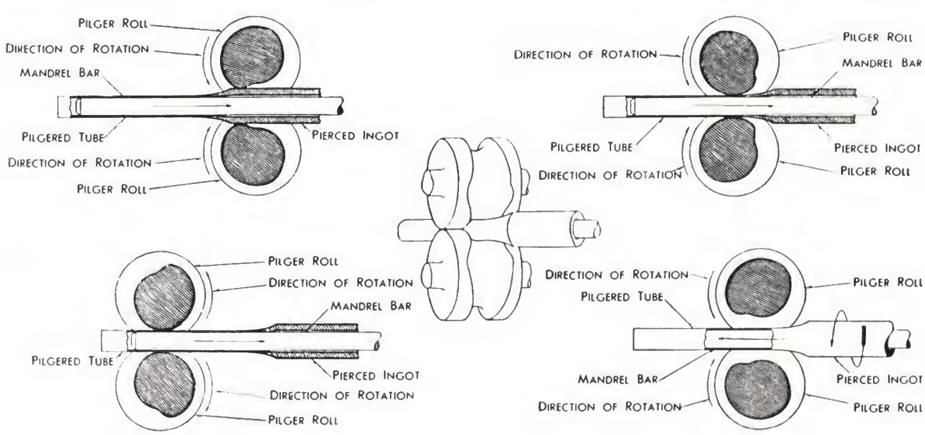


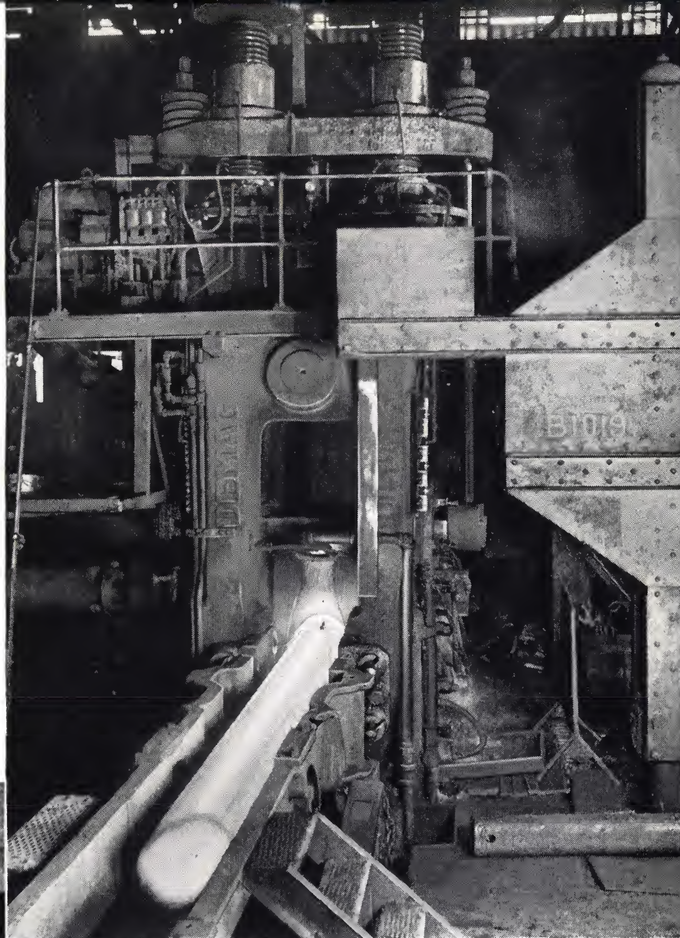
Above: Second piercing further reduces wall thickness and elongates the hollow billet or tube.



Forging action of Pilger rolls results from eccentric grooves and reverse movement of rolls.

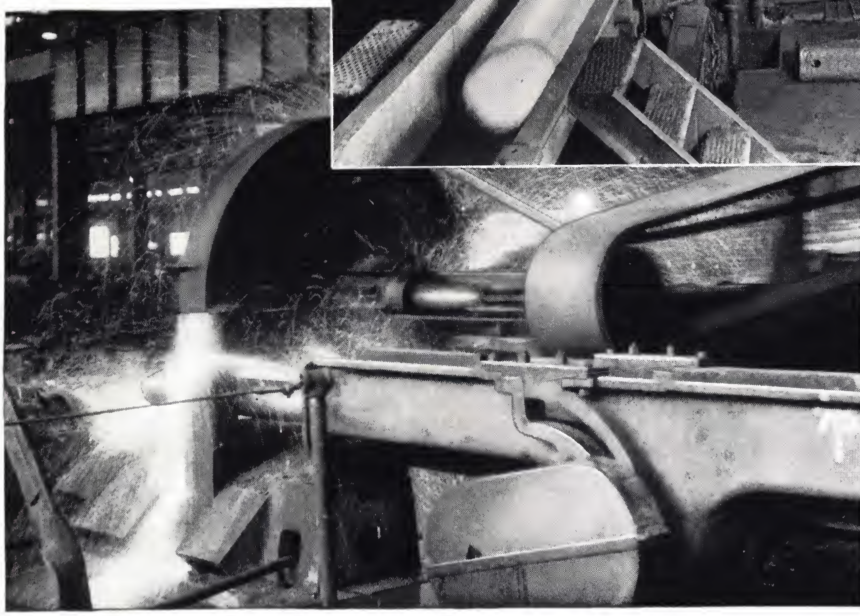
parallel axes, much as are the rolls in an ordinary rolling mill. The big difference between ordinary rolls and Pilger rolls, however, is in the shape of the Pilger rolls, which have eccentric passes designed in such a way that while during the first part of each revolution they actually forge the pipe by delivering severe blows, they roll it in the normal way — though in the reverse direction — during the balance of the revolution. The hot pierced ingot is brought to the Pilger rolls and transferred to the delivery trough of the mill where a mandrel on a hydraulic plunger mounted on a large movable table is inserted





The pipe or tube emerges from Pilger rolls at approximately its finished dimensions.

Below: Discard ends are cropped at the hot saw, and test rings are cut for checking dimensions.



into and through the blank until its forward end projects into the space between the rolls. As the rolls revolve, the blank is forced between the rolls where their surfaces are cut away, then struck a heavy blow in the sharply narrowing throat. As the pass continues to narrow, the pipe is seized and rolled. Since the direction of roll movement is against the pipe, however, rather than with it, as is customary practice, the forged and rolled end of the pipe is thrown backward to the limit allowed by the hydraulic mandrel upon which it is supported. At the same time the mandrel and pipe are mechanically

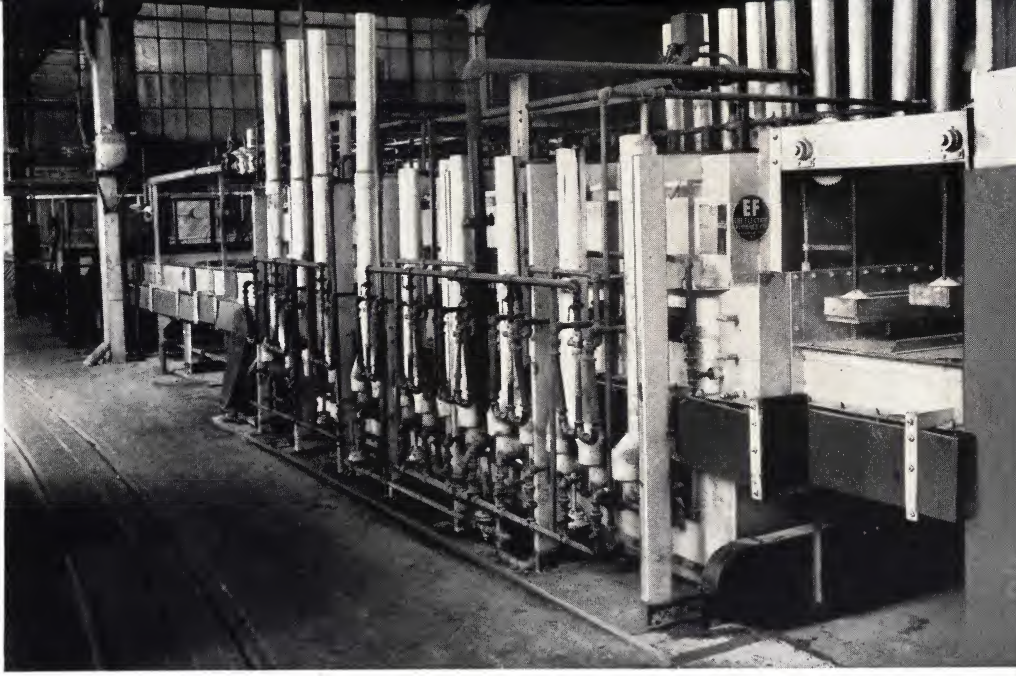
rotated 90°, again the pipe is carried forward into the rolls, struck a hard blow, rolled out and thrown back. This action is repeated many times during Pilgering of a length of pipe until every square inch has been both forged and rolled. The pipe emerges from the rolls slightly oversize in diameter, but of proper wall thickness. Rough ends are sawed off while the pipe is still almost cherry red, after which it is conveyed to the normalizing furnace.

NORMALIZING

Pilger pipe and tubing is stress relieved, and reheated for further operations.

The normalizing furnace at the Pilger Mill is a gas-fired furnace, so arranged that the pipe to be normalized is conveyed on specially designed water-cooled rolls through an opening in one end. The pipe is gradually heated to the proper normalizing temperature as it rolls across the floor or hearth to the opposite side, where it is picked up by a second set of conveyor rolls, passed out of the furnace, and thence on to further finishing operations to be described.

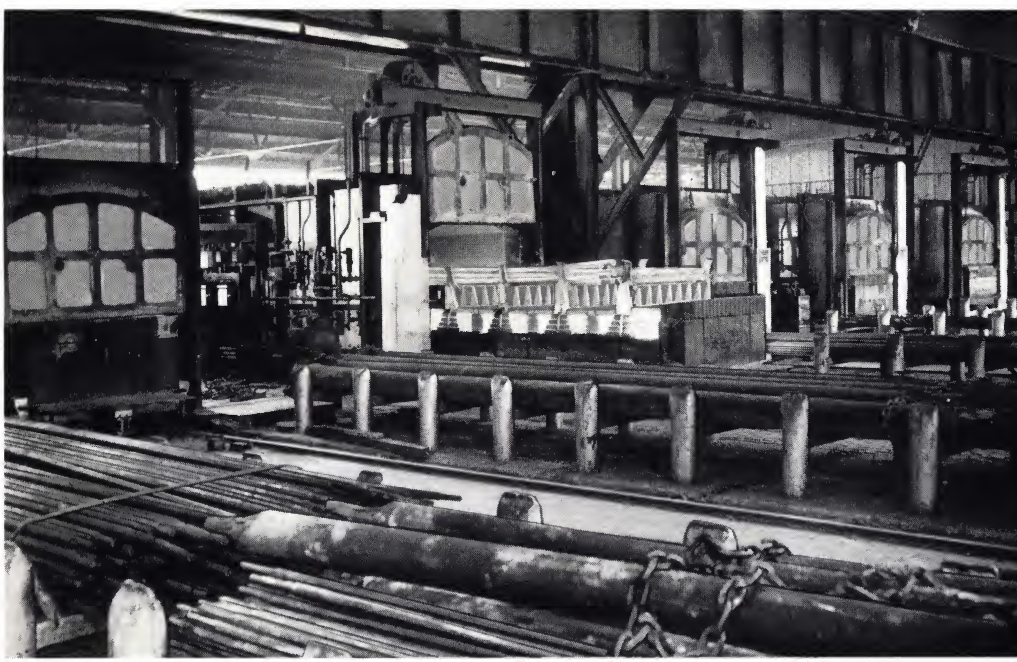
By this normalizing operation, under close temperature control, all work strains are relieved and the grain structure of the steel restored to its ideal condition. This assures that each length of pipe has the same uniformity of structure throughout.



Tubes are thoroughly annealed in this continuous scientifically controlled furnace.

Annealing: When a tube has been cold drawn to finished size it may or may not be annealed, depending upon the use for which it is intended. Boiler tubes, for example, must be full-annealed to bring the grain structure to "dead soft" condition. Various classes of mechanical tubing are annealed at various temperatures, all according to what physical characteristics it may be desired to produce for the service for which the tubing is intended.

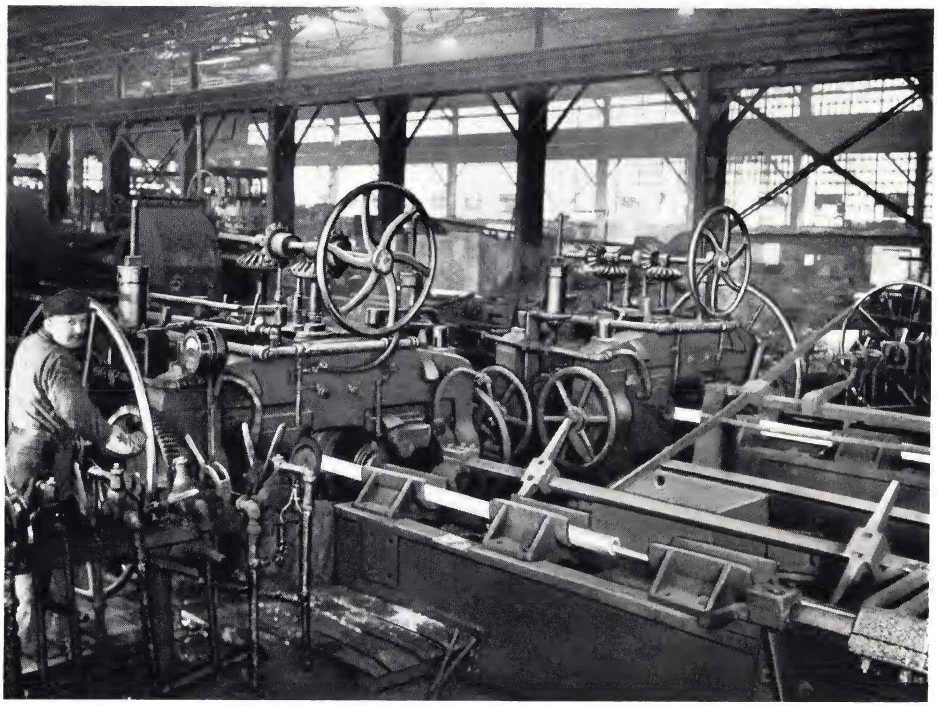
Battery of car-type annealing furnaces.



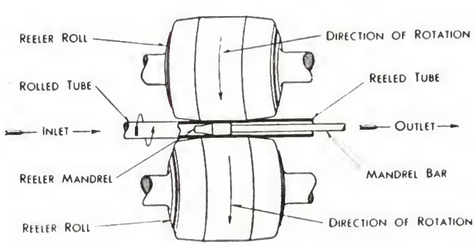
REELING SEAMLESS TUBES

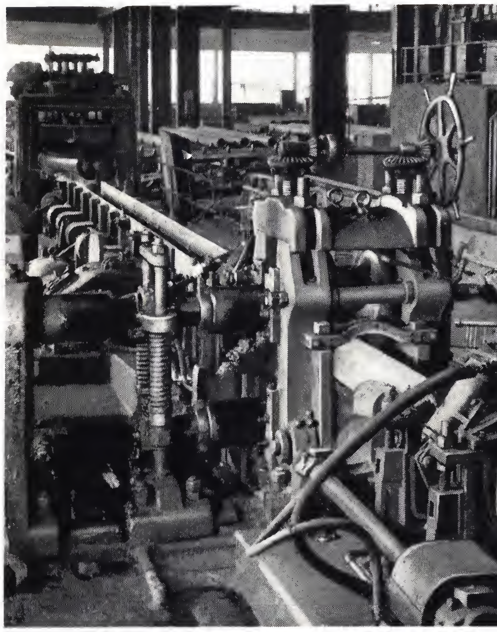
As the tubes come from the rolling mills previously described, they are slightly oval shaped, oversize, and not perfectly smooth. To correct these conditions it is necessary to put them through three finishing operations, the first of which is "reeling."

The reeling mill consists of two short heavy rolls mounted side by side with their axes inclined slightly toward the horizontal. The rolls thus cross each other at their centers. Each roll is adjustable laterally so that the pass between them may be varied by thousandths of an inch. A plug is supported on a mandrel bar at the back of the rolls as at the roll mill. In operation a tube, still retaining enough of its original billet heat to make it a cherry red, is introduced into the reeling mill where it is seized, forced between the swiftly revolving rolls, over the mandrel plug, and out of the mill. The tube is now perfectly round, practically straight, and highly burnished. It is still slightly oversize, a condition which will be remedied in the "sizing" operation.

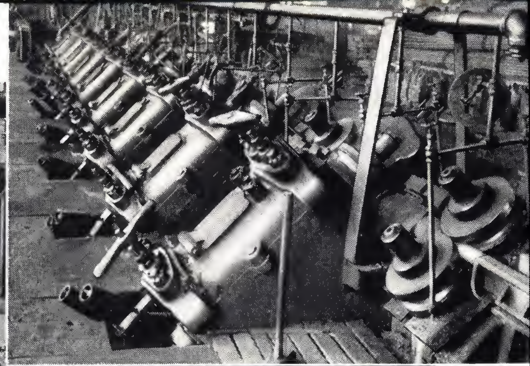


Reeling tubes at No. 4 seamless tube mill, sometimes called "polishing."





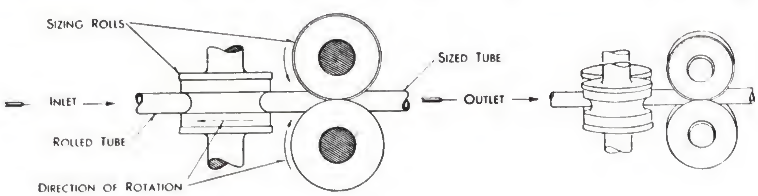
The sizing operation employed for tubes 3" and larger in size.



Hot-reducing is employed for tubes smaller than 3", and results in greater percentage of reduction in sizes.

SIZING AND HOT REDUCING SEAMLESS TUBES

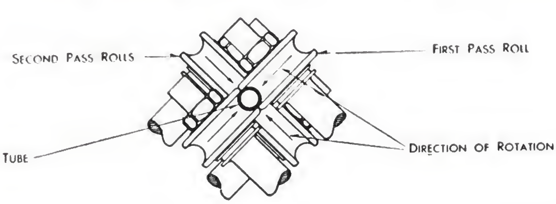
The sizing mill for tubes 3 inches and larger in diameter employs horizontal and vertical rolls, all set with their passes in a horizontal line with all other passes in the stand, these passes being grooved to form a perfect round of the desired outside diameter of the finished tube. The tube is introduced into the sizing



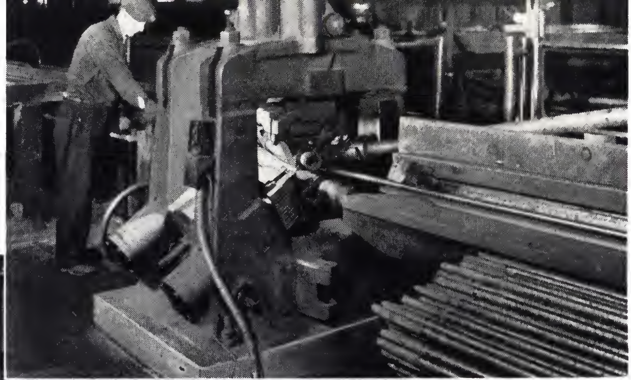
mill — this time without a mandrel — which draws it slowly through, compressing the slightly oversize walls to give the tube its specified outside diameter.

Hot Reducing: Tubes smaller than 3 inches in outside diameter are reheated and finished by a "hot reducing" process which is similar to the sizing operation except that each of the 18 stands of rolls in the hot reducing mill presents a slightly smaller pass to the hot tube as it comes through the mill. By this process it is possible to produce hot rolled tubes as small as $1\frac{1}{2}$" O.D.

While these finishing operations of sizing and hot reducing have their counterparts in the Pilger and Elongator mills respectively, these operations will not be detailed here because of their essential similarity to what has already been described.



The three-roll straightener both straightens and in a degree adds a smoother surface finish to the tube.

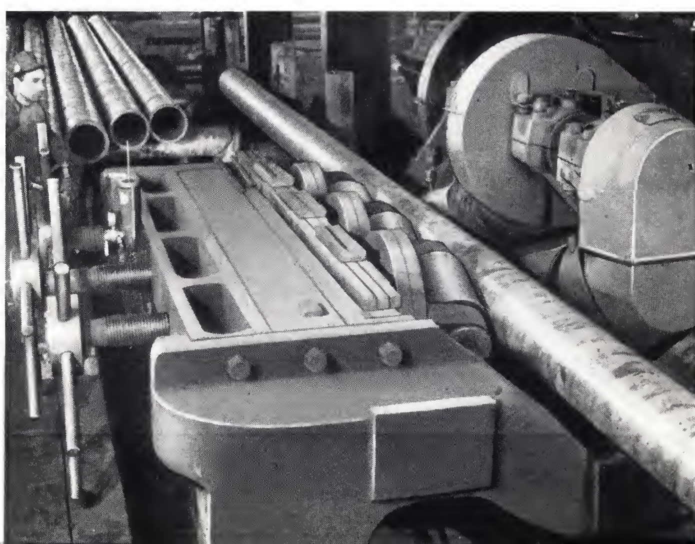


The hot straightening is a preliminary process for approximate straightening of large tubes.

STRAIGHTENING SEAMLESS TUBES

In order to get completely straight pipe and tubes we run all tubular materials, by whatever processes produced, through straightening mills of which there are a number of different types. Each of these straighteners is designed for a particular type of pipe or tube, each turning out a commercially straight product within close limits of tolerance.

After straightening, crop ends are cut from each piece of pipe or tube and — following close final inspection for size, gage, and surface, and tests for strength — the hot rolled product is ready to be prepared for shipment.



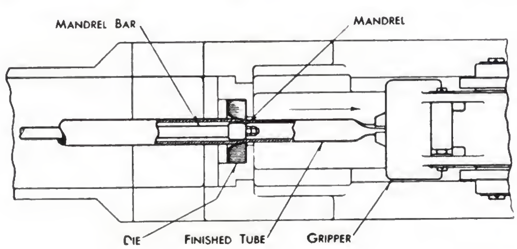
Final straightening of large size tubing is performed in this large Abramsen straightener.

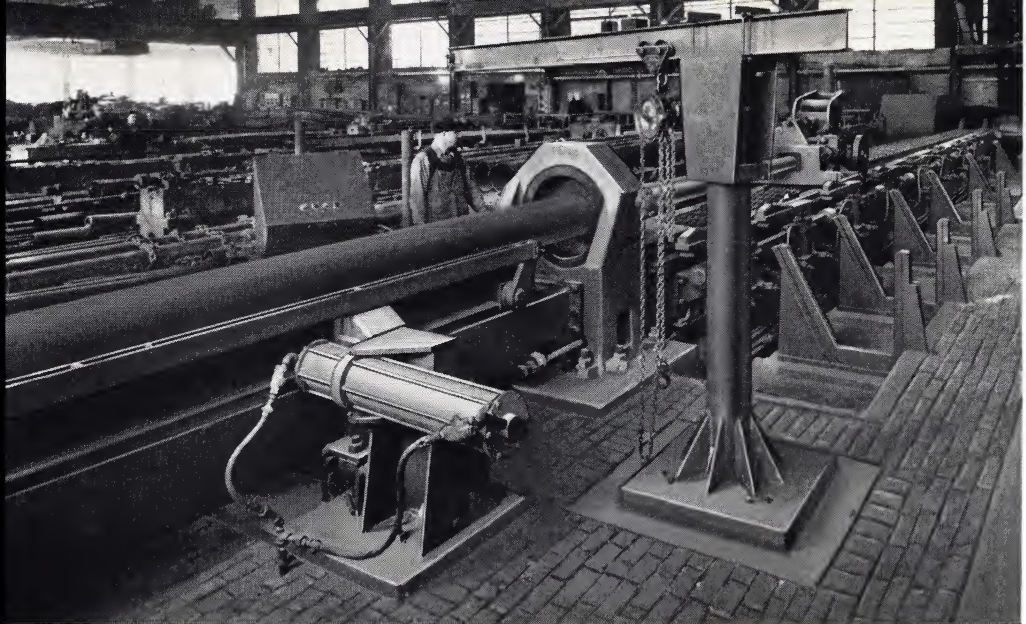
COLD DRAWN TUBING

In general, when tubing is cold drawn after hot rolling, the cold drawing is done to produce lighter walls and to secure a greater degree of accuracy in all dimensions than would be possible by hot finishing. Cold drawing also produces a bright finish on the surfaces of the tubing and imparts increased strength and stiffness through modification of the grain structure of the steel. It is necessary to relieve this stiffness after each cold draw pass by controlled annealing, which restores the normal grain structure.

Hot pointing of tubes in preparation for cold drawing.

Cold drawing begins where hot finishing ends — after the sizing mill. The process itself consists of pulling the tubing by drawing-tongs of tremendous power through round dies of the required smaller sizes. First the tube to be cold drawn is swaged — or pointed — at the end which must start through the die. Next it is pickled in acid for removal of all traces of rolling mill scale, then washed and dried. It is then treated inside and out with a liquid mixture





Heavy automatic cold drawbench for tubes up to 12¾" O.D. with walls ranging from .083" to 1.500"

of flour and tallow or other suitable lubricant. When this lubricant has dried, the tube is ready for the drawing.

Before each cold draw pass the tubes are pickled to remove scale, and dipped in a lubrication solution.

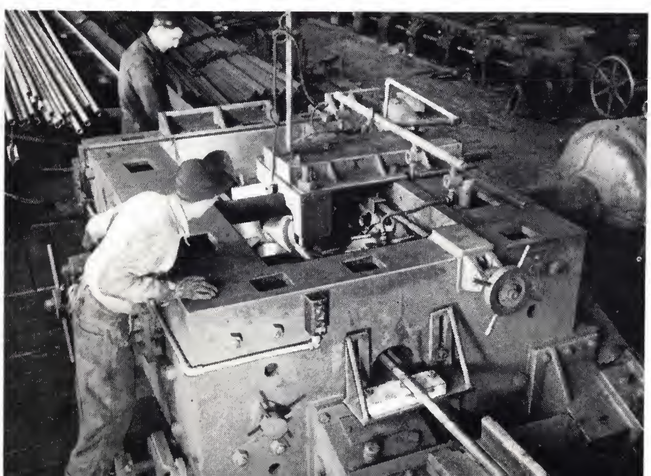
There are two chief processes of cold drawing — the "pulling" process and the "sinking" process. In "pulling" the pointed end of the tube is inserted through the die and gripped on the other side by drawing-tongs. At the same time a mandrel, attached to the end of a long rod, is pushed into the tube from the open end all the way down to the die. When drawing-tongs are engaged with the endless chain of the drawbench and start pulling the tube through the die, the mandrel on the inside of the tube centers itself in the die opening, where it remains until the entire tube is drawn over it. In this way, wall thickness is closely controlled.

The "sinking" process — used for very heavy walled tubing and for inside diameters of ½ inch or less —is practically the same as the pulling process, with

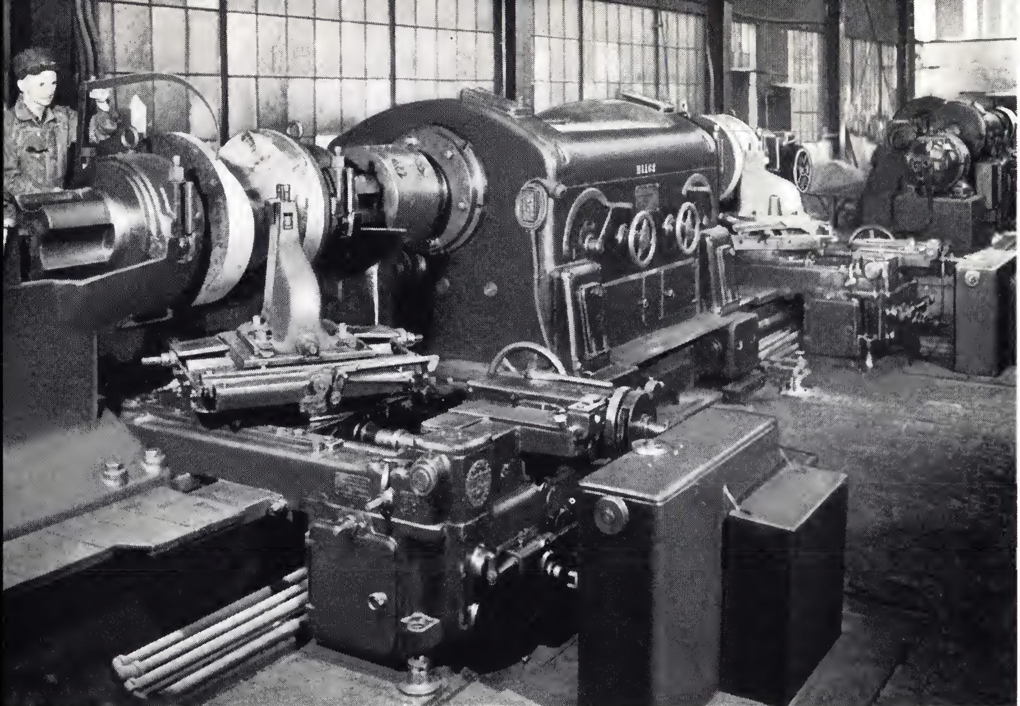
Top: A modern high speed automatic cold drawbench for tubes from $1\frac{1}{4}''$ to $2\frac{1}{2}''$ O.D.
Bottom: One of a battery of cold drawbenches in the Stainless Steel tube department.

the exception that no mandrel is used. This process obviously does not permit altogether accurate control of wall thickness.

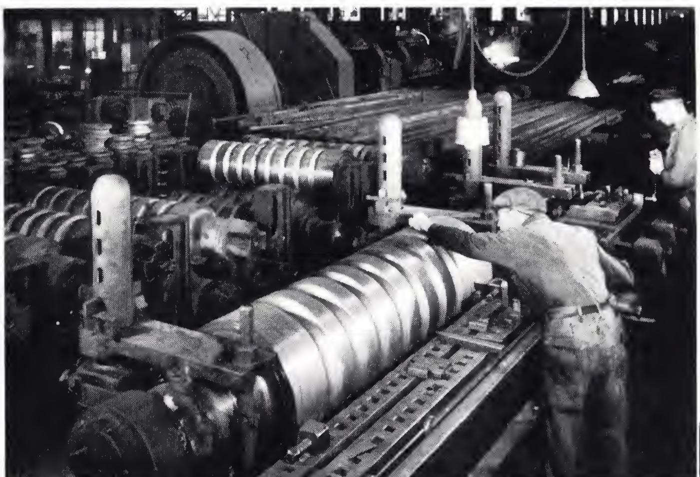
In some cases one cold draw is sufficient to finish a tube to size, but usually it is necessary to give it two or even six or eight — and in some cases as high as twenty — passes through dies of decreasing diameters before the required size is reached. After each pass the tube must be annealed, cleaned, lubricated, and dried before the next pass.



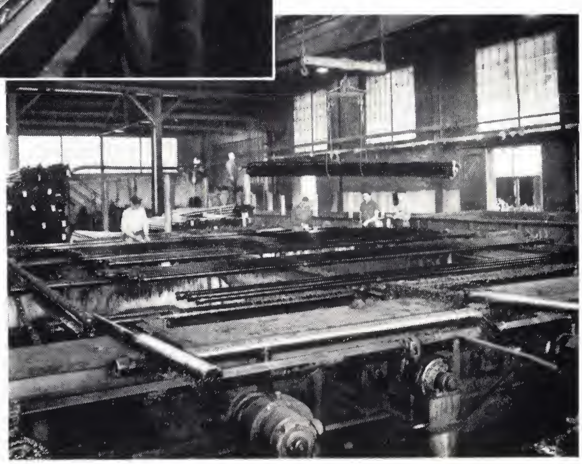
A modern Abramsen type straightener for tubes up to 3″ O.D.



Automatic lathes of intricate design turn the eccentric grooves on the Pilger mill rolls.



Roll lathe for the No. 4 tube rolling mill which may be seen in the background.



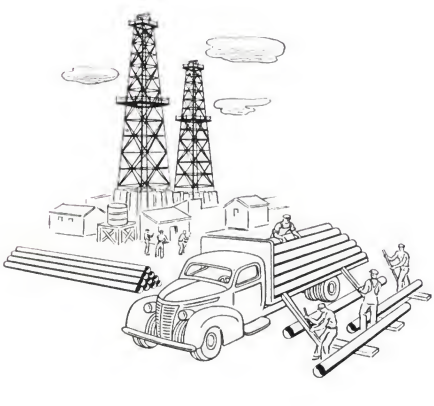
Shipping room where pipe and tubes are loaded for shipment.

Pittsburgh Steel

CATALOG SECTION "P"

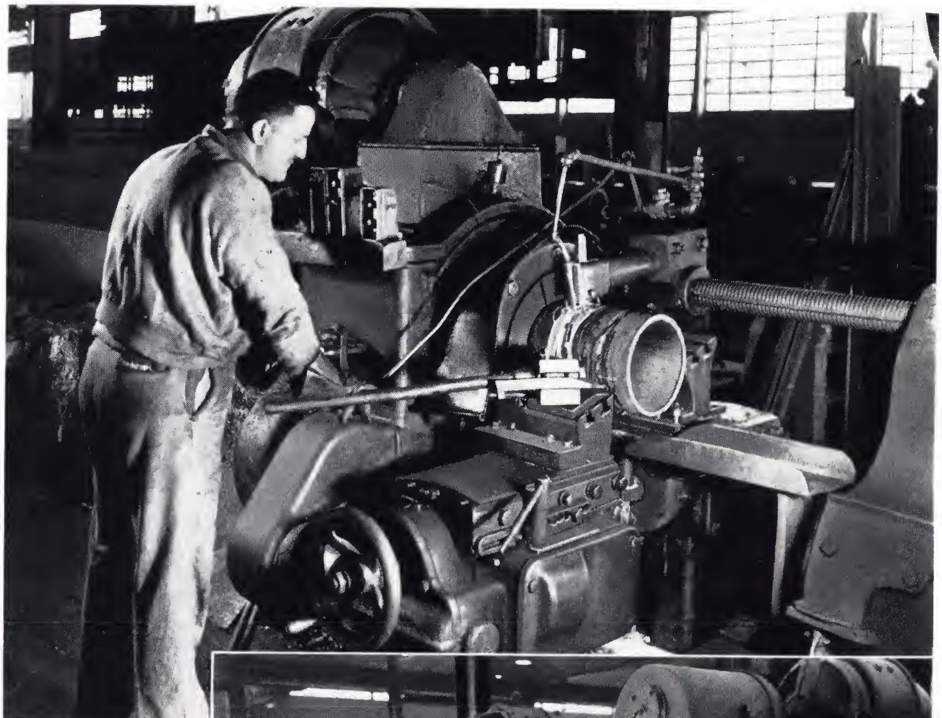
OIL COUNTRY TUBULAR GOODS

LINE PIPE AND STANDARD PIPE

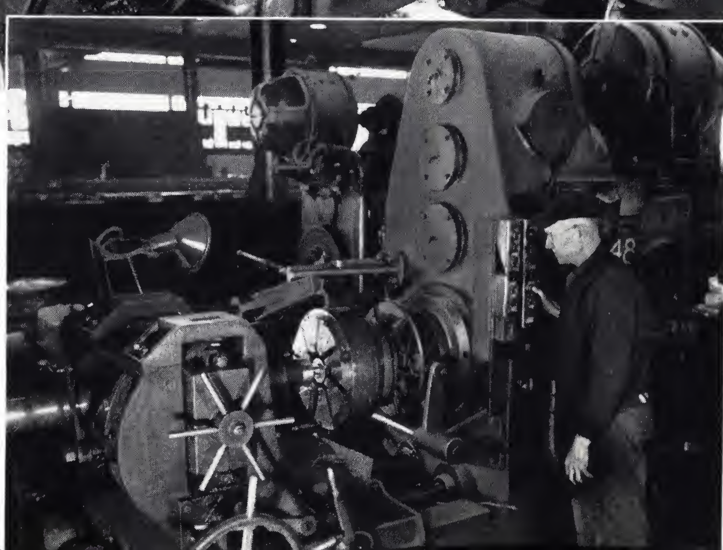


OIL COUNTRY TUBULAR GOODS
Line Pipe and Standard Pipe

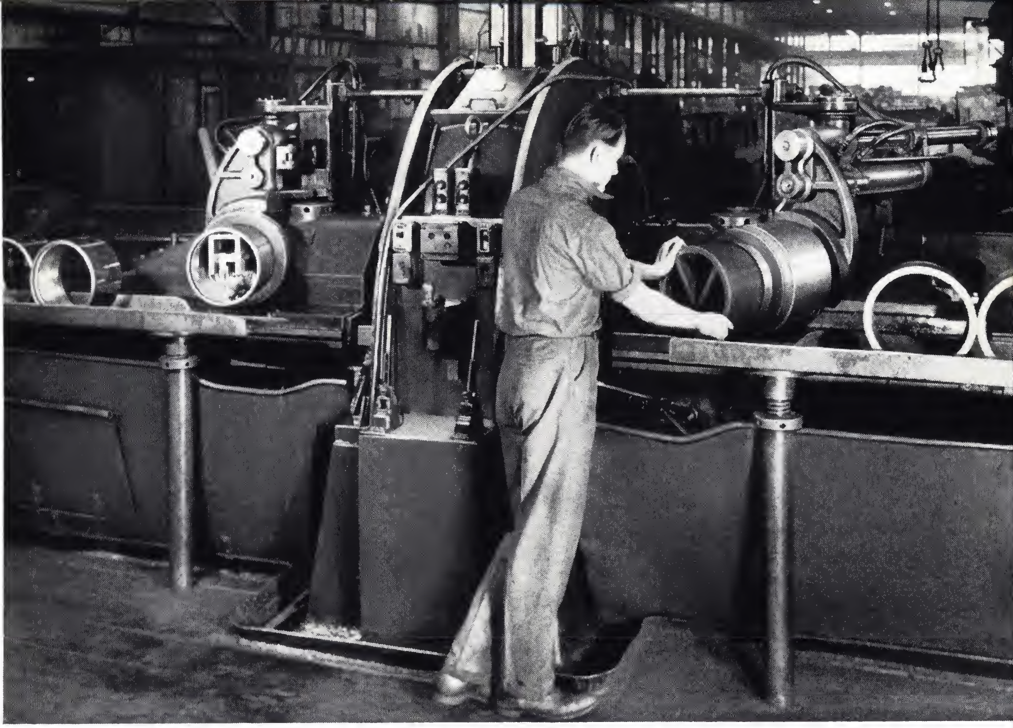
In addition to the basic information covering the manufacture of pipe given in pages G20-G36, there are certain operations applicable especially to Oil Country Tubular Goods, Line Pipe and Standard Pipe. The pipe cut-off machines are equipped to provide, when desired, beveled ends for welding or chamfered ends to receive the threading dies.



Imperfect ends of pipe and tubing are discarded at the cut-off machines.



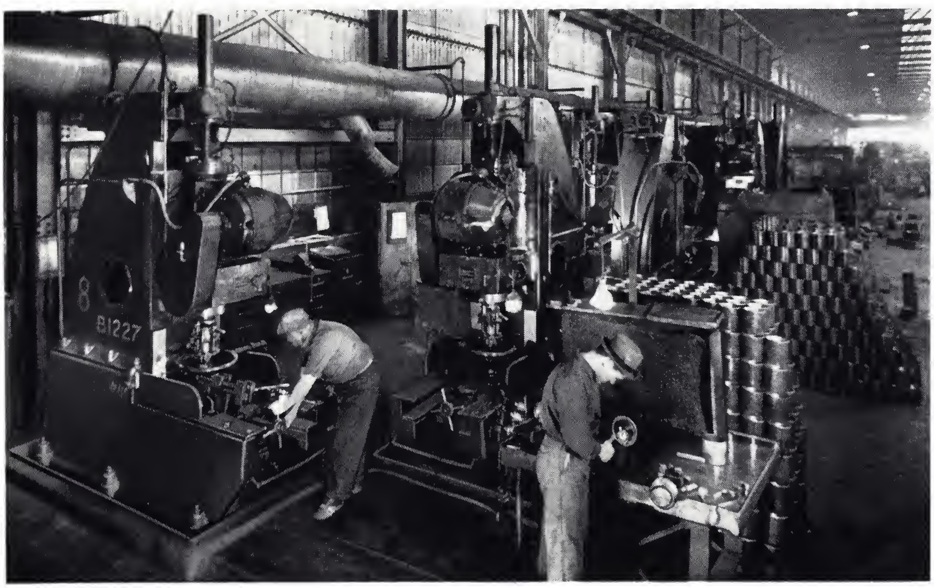
Pipe threads are accurately cut on modern pipe threading machines.

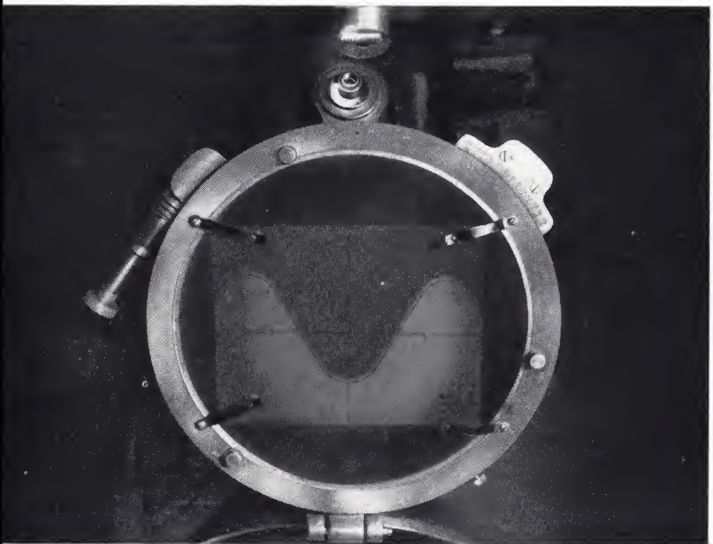


Couplings are first bored to the correct taper on coupling machines.

Pipe threading, particularly for the severe conditions of pressures, tension and rotation encountered in oil country service, must be extremely accurate. After passing all inspections up to this point, each pipe end is tapered and threaded in a single operation, inspected, and immediately covered with a thread protector. Pipe threading machines are arranged in the mill in pairs, and after the first end is threaded, the pipe moves directly to the second machine for tapering and threading the opposite end.

After boring, couplings are threaded on modern equipment, and rigidly inspected.

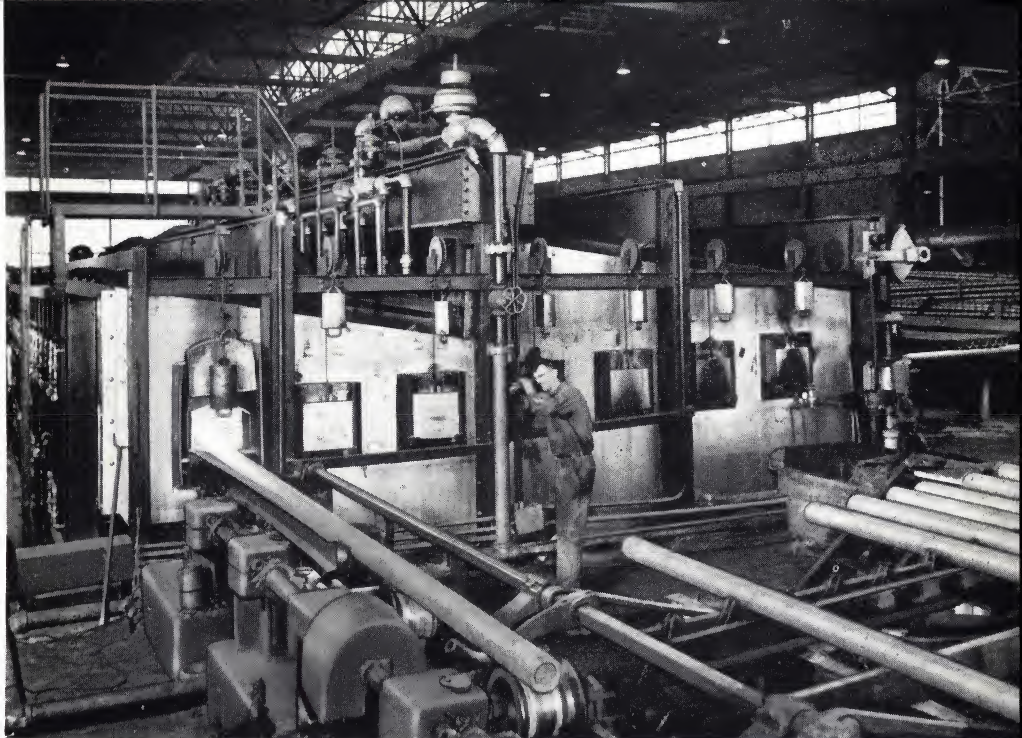




Samples from the threading machines are magnified and compared with perfect thread outlines.

Couplings likewise are accurately made to rigid specifications. The coupling blanks are first bored out with the correct taper from each end to the center on a special coupling machine, then the threads cut on the threading machines. Pipe and coupling threads, in every case, are carefully inspected for accuracy of lead, taper and form; also from time to time a sample section of thread is cut from the pipe and coupling, and measured for accuracy in the thread comparator in which the thread as produced by the threading machine is matched against a perfect outline at $62\frac{1}{2}$ magnifications.

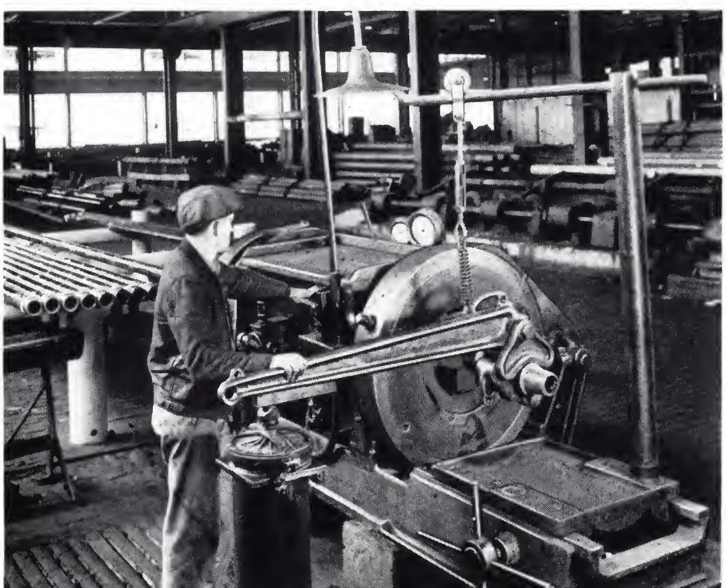
Drill pipe end heater and upsetter for internal upset and external upset internal flush drill pipe.



Entire length of upset drill pipe is normalized in accurately controlled normalizing furnace.

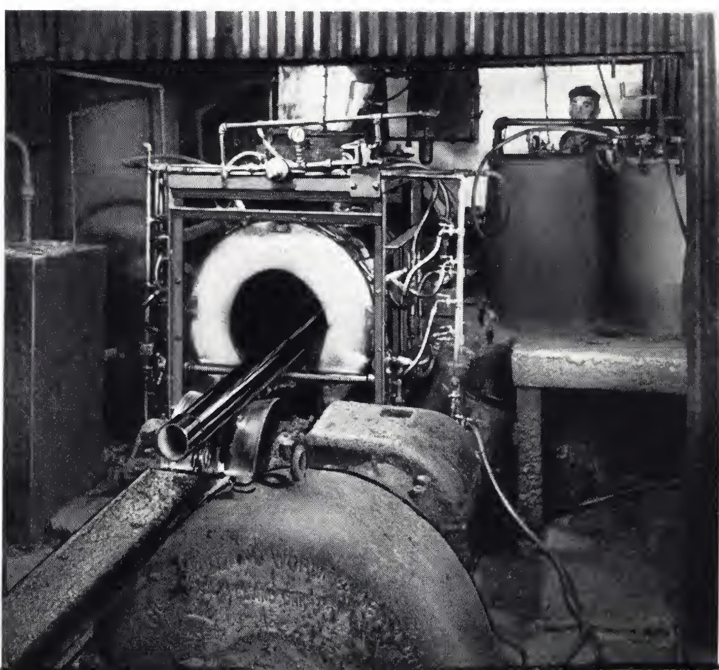
When extra joint strength is required, as in the case of rotary drill pipe, the thickness of the walls at the ends of the pipe is increased by upsetting. The ends of the pipe are heated to the desired temperature, then pass promptly to the upsetter where usually several inches of the end of the pipe, depending upon the amount of upset, are forged back into the area of built-up strength. When both ends are thus upset, the pipe goes to a special furnace where the upsetting stresses, and any other stresses occurring throughout the length of the pipe are removed by normalizing.

Tool joints are bucked on at the mill when this service is desired. (*See P29.*)



Casing is given hydrostatic test in tension, similar to field conditions. *(See P28.)*

In service today most drill pipe is coupled throughout with special alloy-steel tool joints. We do not manufacture tool joints, but normally maintain at our mill stocks of the more popular tool joints belonging to the manufacturers of them. When so desired, we are equipped to furnish "Pittsburgh" drill pipe with tool joints properly bucked on.

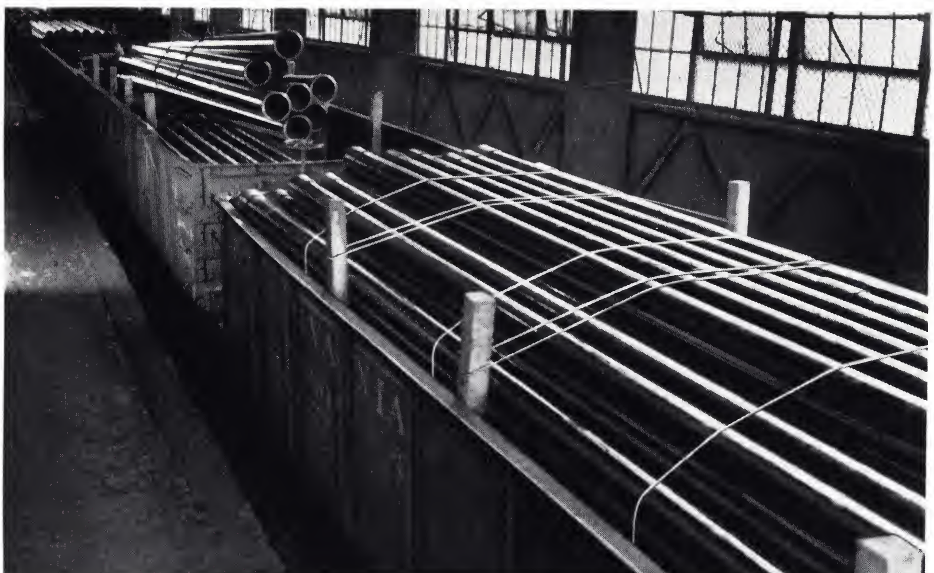


Pipe is cleaned, dried and painted in a continuous operation.

Practically all pipe specifications call for hydrostatic testing at prescribed pressures. This is done after the coupling has been applied to the mill end of the pipe. In the case of Pittsburgh Casing, this test is made *in tension;* see description and advantages on page P28. Plain end pipe must be hydrostatically tested in compression, which is standard practice for all pipe in most other mills.

Each length of pipe is weighed, measured, given final inspections, and stenciled with necessary information.

Following hydrostatic testing, the pipe is prepared for shipment by cleaning, drying, painting, weighing, final inspections and suitable marking. It is then ready for loading upon cars or barges.



Pilger mill shipping room where large pipe and tubes are loaded for shipment.

PITTSBURGH SEAMLESS PIPE

The seamless steel products covered herein are designated as PIPE, as distinguished from Pressure Tubes and Mechanical Tubing.

In general, the term "PIPE," as manufactured by the Pittsburgh Steel Company, applies to:

1. (a) STANDARD PIPE, in nominal sizes 1/8″ to 6″ inclusive; (b) EXTRA STRONG 1/8″ to 12″ inclusive; and (c) DOUBLE EXTRA STRONG, in nominal sizes 1/2″ to 8″ inclusive.

2. LINE PIPE, in sizes 1/8″ nominal to 14″ O.D. inclusive.

3. PRESSURE PIPING, in sizes 1/8″ nominal to 14″ O.D. inclusive.

4. OIL COUNTRY TUBULAR GOODS embracing (a) Casing, in sizes 4 1/2″ to 13 3/8″ O.D., inclusive, (b) Drill Pipe, in sizes 2 3/8″ to 8 5/8″ O.D., inclusive, and (c) Oil Well Tubing, in nominal sizes 1 1/4″ to 4″ inclusive.

General Information

Weights are calculated on the basis of .2833 lbs. per cubic inch of steel and the following formula is generally employed for determining the weight per lineal foot:—

$$W = 10.68\,(D - t)t$$

Where W = Weight in pounds per foot.
D = Outside Diameter in inches.
t = Average Wall Thickness in inches.

All weights given in the following tables are limited to three decimal places.

Standard weight commercial pipe will be finished with threads and couplings in sizes up to and including 12″ unless otherwise specified. It is understood that random lengths finished with threads both ends and coupling one end will be shipped and the measurement charged from end to end, including coupling. "Extra Strong" and "Double Extra Strong" pipe will be furnished with Plain Ends unless otherwise specified.

Commercial pipe is threaded to American Standard (Briggs') working gages.

Material ordered to A P I Standards will be threaded in accordance with those standards.

If cut lengths of Standard Weight, Extra Strong or Double Extra Strong are ordered, instructions must be given on the order whether the material is to be Plain Ends, Threaded only or Threaded and Coupled. The pipe will be cut to the proper length as specified for Plain End or Threaded, but if cut lengths with threads and couplings are specified, the order must state whether the length is for the pipe only or for the overall measurement including the coupling. All couplings for cut length pipe are charged separately whether they are shipped loose or attached to the pipe.

Sizes 14″ and upward are furnished only with Plain Ends or Beveled for Welding.

Material so specified will be cut to length with extreme variation not exceeding 1/8″ over or under unless otherwise arranged.

In calculating lineal footage of threaded and coupled pipe required for laying long lines, make allowance for the distance that pipe will be screwed into the coupling in the field. The customary allowance is one-half the length of the coupling.

Specifications

Pittsburgh Seamless Standard Pipe is usually furnished "Hot Finished," although in certain sizes and for certain purposes it may be ordered "Cold Drawn." Unless specifically ordered otherwise, Pittsburgh Seamless Standard Pipe will be manufactured and tested in accordance with A.S.T.M. Specification A-53 (Grade A) of latest issue.

Line Pipe will be manufactured in accordance with A P I Specification 5-L of latest issue.

Pressure Piping, unless otherwise specified, will be manufactured in accordance with A.S.T.M. Specification A-53 of latest issue.

Oil Country Tubular Goods will be manufactured in accordance with A P I Specifications 5-A of latest issue.

Purchase Orders

The following information should be included in all purchase orders:—

1. Quantity.
2. Size (state whether nominal size or actual O.D.).
3. Weight per foot (or Wall Thickness).
4. Class of Material (whether Hot Finished or Cold Drawn; Standard Pipe, Line Pipe, Pressure Pipe, or Oil Country Casing, Drill Pipe, Oil Well Tubing, etc.).
5. Applicable Specification Number and Grade (A.S.T.M. A-53, Grade A, etc.; A P I 5-A, Grade H-40, J-55, N-80, etc.).
6. Finish (Plain End, Beveled End, Upset, Threaded, etc.).
7. Length, (Random, Average or Cut, or A P I Ranges).
8. Delivery date desired.
9. Inspection (whether Mill Inspection or otherwise).

Dimensional Tolerances for Pipe

PERMISSIBLE VARIATIONS IN OUTSIDE DIAMETER

Class	Size	Reference Specifications	Permissible Variations	
			Over	Under
Standard Pipe Pressure Pipe Line Pipe	Nominal 1/8" to 1 1/2"	A I S I Sect. 18	1/64"	1/32"
	2" or over	A P I 5-L	1 per cent	1 per cent
Oil Country Casing, Drill Pipe and Oil Well Tubing	Nominal 1 1/4" to 4" inc.	A P I 5-A	1/32"	1/32"
	Over 4"	A P I 5-A	0.75 per cent	0.75 per cent

PERMISSIBLE VARIATIONS IN WALL THICKNESS

For all pipe, including Oil Country Tubular Goods, the wall thickness at any point shall not be more than 12 1/2 per cent under the nominal wall thickness specified.

PERMISSIBLE VARIATIONS IN WEIGHT

Class	Size	Reference Specifications	Permissible Variations	
			Over	Under
Pipe, Standard Wt. and Extra Strong	1/8" to 12"	A I S I Sect. 18	5 per cent	5 per cent
Double Extra Strong	1/2" to 8"	A I S I Sect. 18	10 per cent	10 per cent
Line Pipe Threaded	1/8" to 14"	A P I 5-L	10 per cent	3 1/2 per cent
Line Pipe Light Wt. Plain End	3 1/2" to 14"	A P I 5-L	10 per cent	5 per cent
Carload Weights	1/8" to 14"	A P I 5-L		1.75 per cent
Oil Country Casing, Drill Pipe and Tubing	All Sizes	A P I 5-A	6.5 per cent	3.5 per cent
Carload Weights	All Sizes	A P I 5-A		1.75 per cent

Length Ranges

Unless otherwise specified, pipe lengths will be in accordance with the following regular practice.

1 (a) *Standard Weight Pipe* will be in random lengths of 16 to 22 feet and not exceeding 5 per cent of the total number may be "jointers," which are two pieces coupled together. When ordered with plain ends, 5 per cent may be in lengths of 12 to 16 feet.

(b) *Extra Strong and Double Extra Strong Pipe* will be in random lengths of 12 to 22 feet. Five per cent may be in lengths of 6 to 12 feet.

2 (a) *Line Pipe, Threaded and Coupled,* not over 5 per cent under 18 feet, with a minimum of 16 feet for the length of any joint.

(b) *Line Pipe, Plain End* (Consult A P I Specification 5-L).

3 *Pressure Piping,* unless ordered to specified cut lengths, same as 1 (a) and 1 (b) above.

4 *Oil Country Tubular Goods.*

(a) *Casing.*

Range 1

16 to 25 feet; 95% of any carload must be 18 feet or over, and have a length variation of not more than 6 feet.

Range 2

25 to 34 feet; 95% of any carload must be 28 feet or over, and have a length variation of not more than 5 feet.

Range 3

5% of any carload may have a minimum length of 34 feet; remaining 95% must have a minimum length of 36 feet, with a length variation of not more than 6 feet.

(b) *Drill Pipe.*

Range 1

18 to 22 feet; not more than 5% of any carload shall be less than 20 feet in length, with minimum of 18 feet.

Range 2

27 to 30 feet; not less than 90% of any carload shall have a variation of not more than 2 feet.

Range 3

Minimum length 38 feet. All pipe in any carload shall be within a 4 foot variation. At least 90% of any carload shall be within a 3 foot variation.

No Drill Pipe jointers will be shipped.

(c) *Oil Well Tubing.*

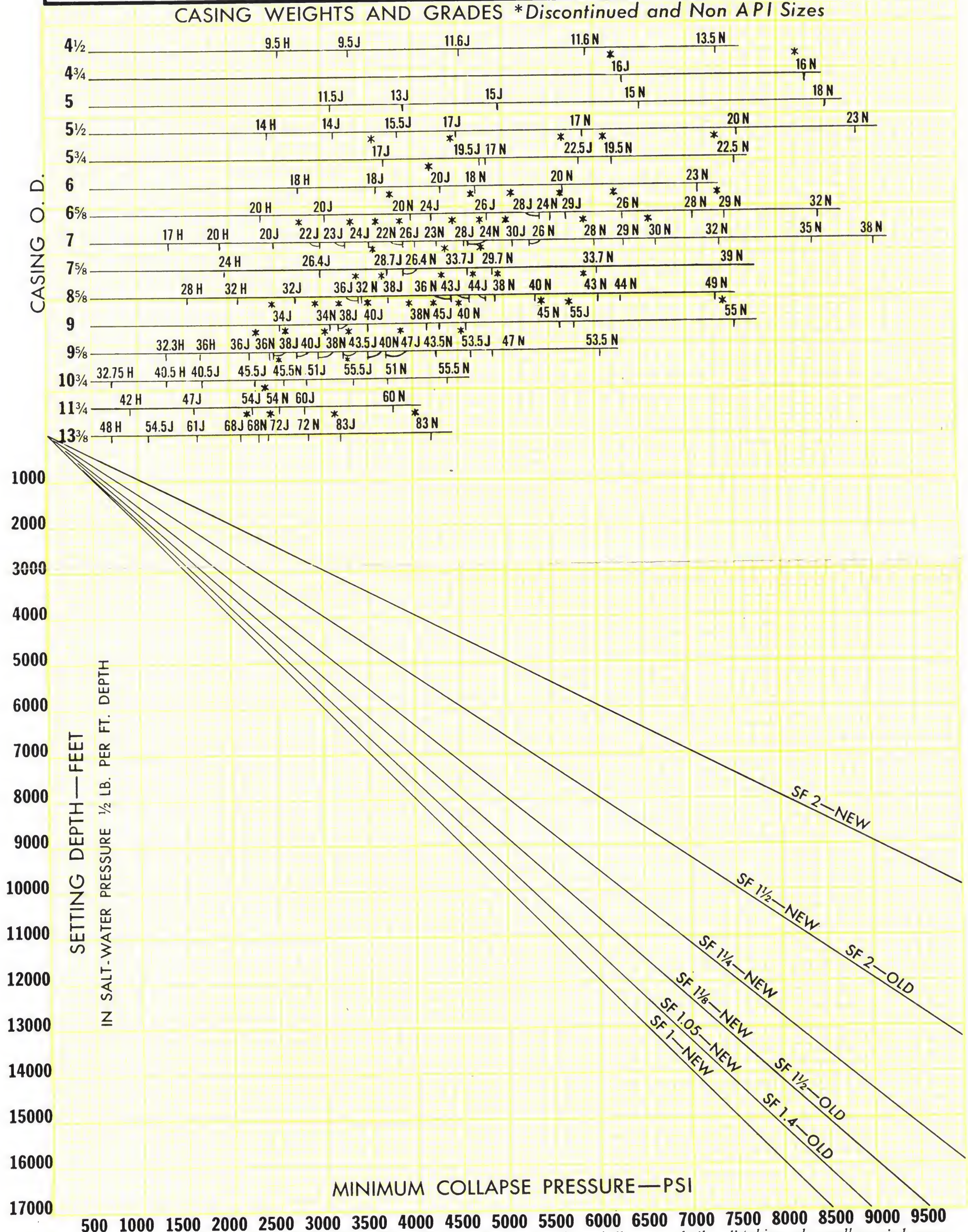
Range 1	20 to 24 feet
Range 2	28 to 32 feet

No Oil Well Tubing jointers will be shipped.

Not more than 2 feet variation in any one car shipped.

COLLAPSE DATA FOR Pittsburgh Special AND API CASING

Based on Minimum Collapse Pressures



 This Chart is also applicable to drill pipe and oil well tubing when collapse is known.

COLLAPSE DATA

For PITTSBURGH SPECIAL and API CASING

The chart on the reverse side is based upon the "New Minimums" figures for collapse pressures and equivalent setting depths for various safety factors as tabulated below. Note comparisons with "Old Averages" figures for collapse pressures and related equivalent setting depths. Computed for salt water pressures at .5 lb. per foot depth.

NEW MINIMUMS					OLD AVERAGES					
Pressure Pounds per Sq. In. or Setting Depth in Feet	Setting Depth in Feet	Setting Depth in Feet	*Setting Depth in Feet*	Setting Depth in Feet	Pressure Pounds per Sq. In. or Setting Depth Feet S.F. 2 (Same as New Min. Setting Depth Feet S.F. 1½)	*Setting Depth Ft. S.F. 1⅛ (Same as New Min. Setting Depth Ft. S.F. 1.125)*	Setting Depth Ft. S.F. 1.4 (Same as New Min. Setting Depth in Ft. S.F. 1.05)	Setting Depth Ft. S.F. 1.3 (Same as New Min. Setting Depth Ft. S.F. .975)	Setting Depth in Ft. S.F. 1.2 (Same as New Min. Setting Depth Ft. S.F. .9)	Setting Depth in Ft. S.F. 1.1 (Same as New Min. Setting Depth in Ft. S.F. .825)
S.F. 2	S.F. 1½	S.F. 1¼	*S.F. 1⅛*	S.F. 1						
710	950	1140	*1260*	1420	950	*1260*	1350	1460	1580	1730
740	990	1180	*1320*	1480	990	*1320*	1410	1520	1650	1810
940	1250	1500	*1670*	1880	1250	*1670*	1790	1930	2090	2280
140	1520	1820	*2030*	2280	1520	*2030*	2170	2340	2530	2760
320	1760	2110	*2350*	2640	1760	*2350*	2510	2710	2930	3200
340	1790	2140	*2380*	2680	1790	*2380*	2550	2750	2980	3260
370	1830	2190	*2440*	2740	1830	*2440*	2610	2810	3050	3320
580	2110	2530	*2810*	3160	2110	*2810*	3010	3240	3510	3830
630	2170	2610	*2900*	3260	2170	*2900*	3100	3340	3620	3950
670	2230	2670	*2970*	3340	2230	*2970*	3180	3430	3710	4050
710	2280	2740	*3040*	3420	2280	*3040*	3260	3510	3800	4140
730	2310	2770	*3080*	3460	2310	*3080*	3300	3550	3850	4200
920	2560	3070	*3420*	3840	2560	*3420*	3660	3940	4260	4650
970	2630	3150	*3500*	3940	2630	*3500*	3750	4040	4380	4790
2060	2750	3300	*3660*	4120	2750	*3660*	3920	4230	4580	5000
2110	2810	3380	*3750*	4220	2810	*3750*	4020	4330	4690	5110
2140	2850	3420	*3800*	4280	2850	*3800*	4080	4390	4750	5190
2220	2960	3550	*3950*	4440	2960	*3950*	4230	4550	4930	5380
2270	3030	3630	*4040*	4540	3030	*4040*	4320	4660	5050	5500
2300	3070	3680	*4090*	4600	3070	*4090*	4380	4720	5110	5580
2360	3150	3780	*4200*	4720	3150	*4200*	4500	4840	5250	5720
2440	3250	3900	*4340*	4880	3250	*4340*	4650	5000	5420	5920
2500	3330	4000	*4440*	5000	3330	*4440*	4760	5140	5560	6060
2550	3400	4080	*4530*	5100	3400	*4530*	4860	5230	5670	6180
2610	3480	4180	*4640*	5220	3480	*4640*	4970	5350	5800	6330
2740	3650	4380	*4870*	5480	3650	*4870*	5220	5620	6090	6640
2770	3690	4430	*4920*	5540	3690	*4920*	5280	5680	6150	6710
2780	3710	4450	*4940*	5560	3710	*4940*	5300	5700	6180	6740
2840	3790	4540	*5050*	5680	3790	*5050*	5410	5830	6310	6890
2870	3830	4590	*5100*	5740	3830	*5100*	5470	5890	6380	6960
2880	3840	4610	*5120*	5760	3840	*5120*	5490	5900	6400	6980
2990	3990	4780	*5320*	5980	3990	*5320*	5700	6130	6650	7250
3010	4010	4820	*5350*	6020	4010	*5350*	5730	6170	6690	7330
3060	4080	4910	*5440*	6120	4080	*5440*	5830	6280	6800	7420
3130	4170	5010	*5560*	6260	4170	*5560*	5960	6420	6950	7590
3170	4230	5070	*5640*	6340	4230	*5640*	6040	6500	7050	7690
3290	4390	5260	*5850*	6580	4390	*5850*	6270	6750	7310	7980
3320	4430	5310	*5900*	6640	4430	*5900*	6320	6810	7380	8050
3420	4560	5470	*6080*	6840	4560	*6080*	6510	7020	7600	8290
3530	4710	5650	*6280*	7060	4710	*6280*	6730	7240	7850	8560
3620	4830	5790	*6430*	7240	4830	*6430*	6900	7420	8050	8780
3710	4950	5940	*6600*	7420	4950	*6600*	7070	7610	8250	9000
3750	5000	6000	*6670*	7500	5000	*6670*	7140	7690	8330	9090
3860	5150	6180	*6860*	7720	5150	*6860*	7350	7930	8580	9350
3930	5240	6290	*6990*	7860	5240	*6990*	7490	8060	8730	9530

NEW MINIMUMS					OLD AVERAGES					
Pressure Pounds per Sq. In. or Setting Depth in Feet	Setting Depth in Feet	Setting Depth in Feet	*Setting Depth in Feet*	Setting Depth in Feet	Pressure Pounds per Sq. In. or Setting Depth Feet S.F. 2 (Same as New Min. Setting Depth Feet S.F. 1½)	*Setting Depth Ft. S.F. 1⅛ (Same as New Min. Setting Depth Ft. S.F. 1.125)*	Setting Depth Ft. S.F. 1.4 (Same as New Min. Setting Depth in Ft. S.F. 1.05)	Setting Depth Ft. S.F. 1.3 (Same as New Min. Setting Depth Ft. S.F. .975)	Setting Depth Ft. S.F. 1.2 (Same as New Min. Setting Depth Ft. S.F. .9)	Setting Depth in Ft. S.F. 1.1 (Same as New Min. Setting Depth in Ft. S.F. .825)
S.F. 2	S.F. 1½	S.F. 1¼	*S.F. 1⅛*	S.F. 1						
4010	5350	6420	*7130*	8020	5350	*7130*	7640	8230	8910	9720
4190	5590	6700	*7450*	8380	5590	*7450*	7980	8590	9310	10160
4250	5670	6800	*7560*	8500	5670	*7560*	8100	8720	9450	10310
4280	5710	6850	*7610*	8560	5710	*7610*	8150	8780	9510	10380
4300	5730	6880	*7640*	8600	5730	*7640*	8190	8820	9550	10420
4420	5890	7070	*7860*	8840	5890	*7860*	8420	9060	9820	10710
4470	5960	7150	*7950*	8940	5960	*7950*	8510	9170	9930	10840
4500	6000	7200	*8000*	9000	6000	*8000*	8570	9230	10000	10910
4540	6050	7260	*8070*	9080	6050	*8070*	8650	9310	10090	11010
4640	6190	7420	*8250*	9280	6190	*8250*	8840	9520	10310	11250
4730	6310	7570	*8410*	9460	6310	*8410*	9010	9700	10510	11470
4840	6450	7740	*8600*	9680	6450	*8600*	9220	9930	10760	11740
4900	6530	7840	*8710*	9800	6530	*8710*	9330	10050	10890	11880
4910	6550	7860	*8730*	9820	6550	*8730*	9350	10070	10910	11890
4980	6640	7970	*8850*	9960	6640	*8850*	9490	10220	11050	12070
5130	6840	8210	*9120*	10260	6840	*9120*	9770	10520	11400	12440
5320	7090	8510	*9460*	10640	7090	*9460*	10130	10900	11820	12900
5390	7190	8630	*9580*	10780	7190	*9580*	10270	11060	11980	13070
5440	7250	8700	*9660*	10880	7250	*9660*	10360	11160	12090	13200
5550	7400	8880	*9870*	11100	7400	*9870*	10570	11380	12330	13450
5690	7590	9100	*10120*	11380	7590	*10120*	10840	11670	12650	13800
5770	7690	9230	*10260*	11540	7690	*10260*	10990	11840	12820	13990
5890	7850	9420	*10470*	11780	7850	*10470*	11220	12080	13090	14290
5930	7910	9490	*10540*	11860	7910	*10540*	11300	12160	13180	14380
6070	8090	9710	*10790*	12140	8090	*10790*	11560	12450	13490	14720
6110	8150	9780	*10860*	12220	8150	*10860*	11640	12530	13580	14810
6220	8290	9950	*11060*	12440	8290	*11060*	11850	12760	13820	15080
6320	8430	10110	*11240*	12640	8430	*11240*	12040	12960	14050	15320
6370	8490	10190	*11320*	12740	8490	*11320*	12130	13070	14150	15440
6520	8690	10430	*11590*	13040	8690	*11590*	12320	13370	14490	15800
6710	8950	10730	*11930*	13420	8950	*11930*	12780	13760	14910	16270
7110	9480	11380	*12640*	14220	9480	*12640*	13540	14580	15800	17240
7180	9570	11490	*12770*	14360	9570	*12770*	13670	14730	15960	17400
7350	9800	11760	*13070*	14700	9800	*13070*	14000	15080	16330	17820
7370	9830	11790	*13100*	14740	9830	*13100*	14040	15120	16380	17870
7400	9870	11840	*13160*	14800	9870	*13160*	14100	15180	16450	17940
7530	10040	12050	*13390*	15060	10040	*13390*	14340	15450	16730	18250
7580	10110	12130	*13480*	15160	10110	*13480*	14440	15550	16850	18380
8330	11110	13330	*14800*	16660	11110	*14800*	15870	17090	18510	20190
8420	11230	13470	*14970*	16840	11230	*14970*	16040	17270	18710	20410
8490	11320	13580	*15090*	16980	11320	*15090*	16170	17420	18870	20580
8550	11400	13680	*15200*	17100	11400	*15200*	16300	17540	19000	20730
8900	11870	14240	*15820*	17800	11870	*15820*	16950	18260	19780	21580
8980	11970	14370	*15960*	17960	11970	*15960*	17100	18420	19950	21770
9080	12110	14530	*16140*	18160	12110	*16140*	17300	18630	20180	22010

For additional copies, address **Pittsburgh Steel Company, Pittsburgh, Pa.**

Pittsburgh Seamless API CASING
SETTING DEPTH PROPERTIES

The data for setting depth properties of casing given on the following pages are based on API Code 5-C-2, Second Edition, May 1942, prepared by the Institute's Committee on Standardization of Oil Country Tubular Goods.

The minimum setting depth properties shown are based on average values given in API Bulletin 5-C-2; revised as follows†:

(I) Collapse resistance minimum to be 75 per cent of the average collapse pressures given in Bul. 5-C-2, Second Edition.

(II) Joint strength minimum to be 80 per cent of the average ultimate strength of joint given in Bul. 5-C-2, Second Edition.

†Chart of Average Properties, Page 14; Minimum Properties, Page 15.

(III) Internal yield pressure minimum to be 87½ per cent of the values given in Bul. 5-C-2, Second Edition, for internal pressure at minimum yield point.

The data on average collapse pressures shown in Bulletin 5-C-2 for seamless apply to pipe with the following average yield strength:

Designation	Minimum Yield Strength (lb. per sq. in.)	Average Yield Strength (lb. per sq. in.)
H-40	40,000	50,000
J-55	55,000	65,000
N-80	80,000	85,000

The data shown for minimum collapsing pressures were determined from collapse test data on hot rolled seamless casing.

AVERAGE COLLAPSING PRESSURES GRADES H-40, J-55 AND N-80

The average collapsing pressures given in Bul. 5-C-2 for Grades H-40, J-55 and N-80 casing were derived by using the following formulae:

For collapsing pressures where failure is elastic:

$$P = \frac{62.6 \times 10^6}{D/t\,(D/t-1)^2} \ldots\ldots (1)^{1*}$$

For collapsing pressures for values of D/t of 14 approximately, and up to and including the point of intersection of the curve for plastic failure with the elastic curve:

$$P = (YP)\left(\frac{2.503}{D/t} - .0460\right) \ldots (2)^{2,4}$$

For collapsing pressures for values of D/t less than 14 approximately:

$$P = \frac{2\,YP\,(D/t-1)}{(D/t)^2} \ldots\ldots\ldots\ldots (3)^2$$

where
- P = collapsing pressure, lb. per sq. in.
- D = outside diameter of casing, inches.
- t = wall thickness of casing, inches.
- YP = average longitudinal tensile yield strength, lb. per sq. in.

*Equation for elastic curve.

[1]Equation (1) was derived from the theoretically determined elastic curve equation:

$$P = \left(\frac{2E}{1-r^2}\right)\left(\frac{1}{D/t\,(D/t-1)^2}\right)$$

Where
- E = Young's modulus of elasticity.
- r = Poisson's ratio.

The curve derived from this equation was found by an examination of available test results to be an upper boundary for all values. The average collapsing pressures as determined from equation (1) are 95 per cent of the theoretical values assuming $E = 30 \times 10^6$ and $r = 0.3$.

[2]Equation (2) is an empirical equation of the Stewart form derived from the result of 409 collapse tests of seamless pipe having yield strengths ranging from 40,000 to 70,000 lb. per sq. in. and incorporates a correction factor to correct for the deviation of the measured average D/t ratio from the nominal D/t ratio. The following values were used as yield strengths:

Designation	Minimum Yield Strength (lb. per sq. in.)	Average Yield Strength (lb. per sq. in.)
H-40	40,000	50,000
J-55	55,000	65,000
N-80	80,000	85,000

[3]Equation (3) is the Lame' equation. Because of the lack of data, the Lame' equation was used in calculating the collapsing pressures of the heavier wall pipe having D/t ratios less than 14 approximately as it was felt to be unsafe to let the estimated stress at collapse exceed the yield strength.

[4]The collapse curve for Grade H-40 was adjusted for its intersection with the elastic curve. This was done by changing its curvature at D/t = 30 (the limit of the test data from which the curve was derived), and intersecting the elastic curve at D/t = 40. This procedure made the curve consistent with the experimental lapweld curve derived from Dr. Stewart's formulae and which intersects the elastic curve at about D/t = 44.

AVERAGE JOINT STRENGTH

The average joint strengths for casing given in Bul. 5-C-2 were calculated by the following formulas:

Short Couplings:

$$P = C\,(33.71 - D)\left(\frac{1}{t-0.07125} + 24.45\right) A_j$$

Long Couplings:

$$P = C\,(25.58 - D)\left(\frac{1}{t-0.07125} + 24.45\right) A_j$$

$$A_j = .7854\,\left((D-0.1425)^2 - d^2\right)$$

where
- P = average joint strength, pounds.
- D = outside diameter of the casing, inches.
- d = inside diameter of the casing, inches.
- t = wall thickness of casing, inches.
- Aj = cross sectional area; square inches.
- C = a constant for the steel grade.

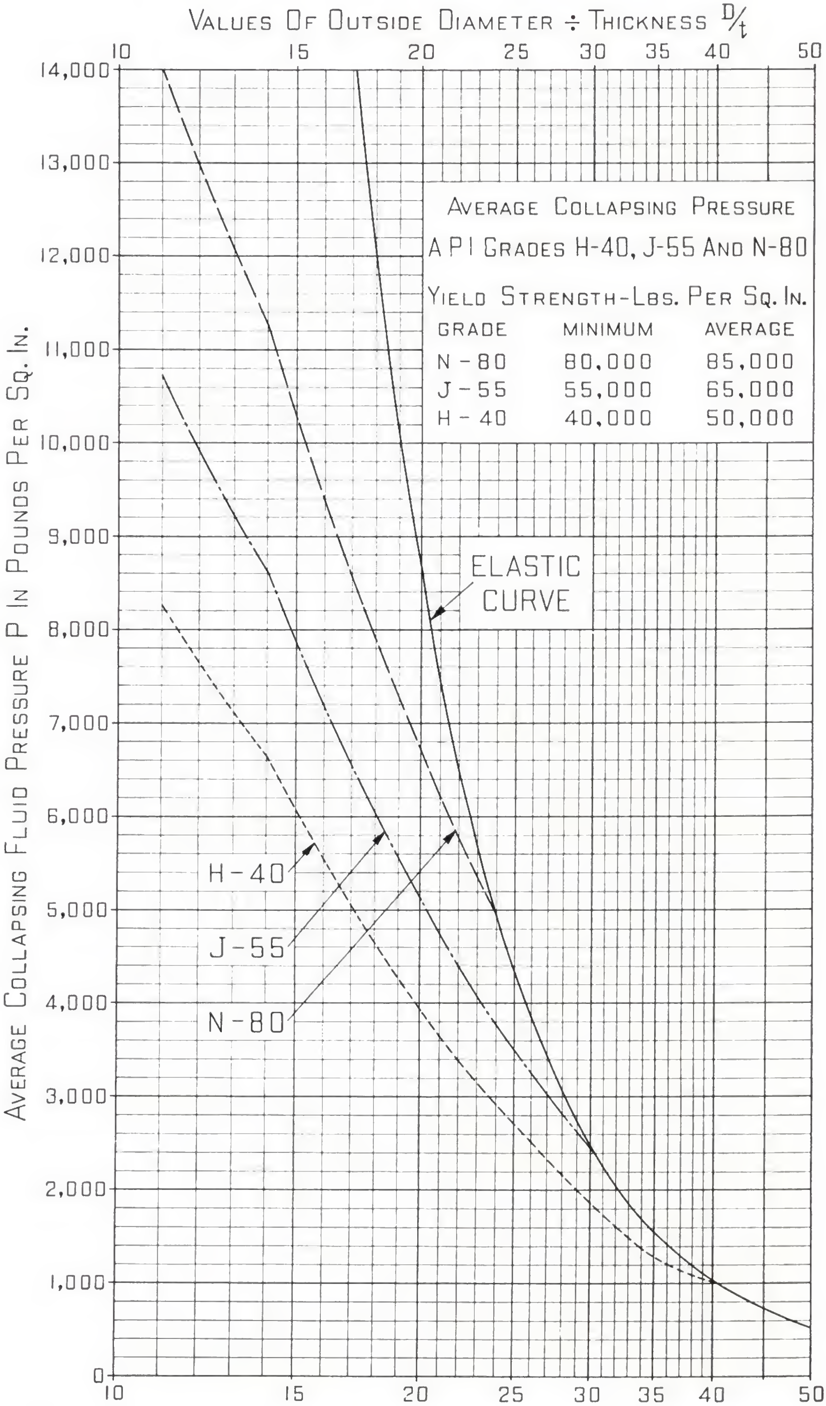
VALUES FOR C

	Short Coupling	Long Coupling
Grade H-40	72.5	...
J-55	96.5	159
N-80	112.3	185

NOTE: The values in the table are subject to the small error arising from rounding out the average and then again for the minimum.

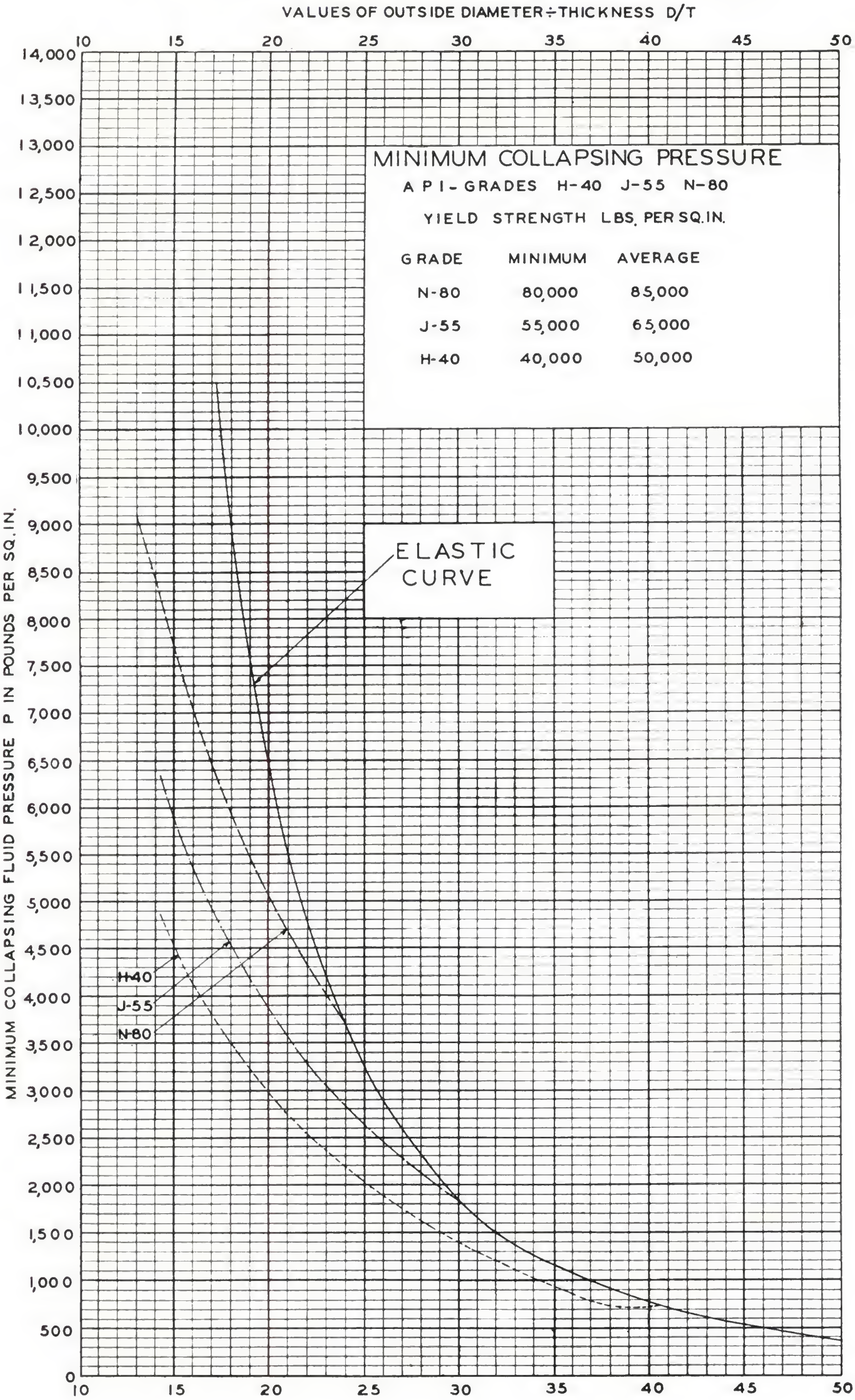
The formulas for joint strength are based on a large, but unknown, number of joint tests which were summarized to a straight line expression for the joint efficiency; that is, the ratio of the load causing failure to the load calculated from the net area and the strength of the material in the joint tested. The notch effect factor was determined by tests of notched tensile specimens.

Average Collapsing Pressures



Reproduced from Standards 5A, 10th edition, by permission of the American Petroleum Institute.

MINIMUM COLLAPSING PRESSURES



**PITTSBURGH SEAMLESS A P I STANDARD ROUND THREAD CASING

†Long and Short Threads and Couplings PART I

Size—Outside Diameter	Weight Per Foot		††GRADE H-40					††GRADE J-55							††GRADE N-80						
			Collapsing Pressures		Minimum Tensile Strength of Joint			Collapsing Pressures		Minimum Tensile Strength of Joint					Collapsing Pressures		Minimum Tensile Strength of Joint				
			Short Threads							Short Threads		Long Threads					†Short Threads		Long Threads		
	Nominal Threads and Couplings	Plain End	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2	1000 Pounds	Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2	1000 Pounds	Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.		Ft.	Lbs.
* 4½	*9.50*	9.40	2550	4530	96	5050	3190	3320	5900	128	6730			4380							
* 4½	*11.60*	11.35						4540	8070	159	6850	189	8150	5350	5930	10540	185	7970	220	9480	7780
* 4½	*13.50*	13.04													7350	13070	217	8040	258	9560	9020
* 5	*11.50*	11.23						3130	5560	152	6610			4240							
* 5	*13.00*	12.83						3930	6990	178	6840	210	8080	4870							
* 5	*15.00*	14.87						4980	8850	210	7000	247	8230	5700	6520	11590	244	8130	288	9600	8290
* 5	*18.00*	17.93													8550	15200	300	8330	354	9830	10140
5½	*14.00*	13.70	2440	4340	139	4960	3110	3170	5640	186	6640			4270							
* 5½	*15.50*	15.35						3860	6860	211	6800	247	7970	4810							
5½	*17.00*	16.87						4500	8000	234	6880	275	8090	5320	5890	10470	273	8030	320	9410	7740
5½	*20.00*	19.81													7580	13480	326	8150	382	9550	9190
* 5½	*23.00*	22.54													8900	15820	375	8150	440	9570	10560
6	*18.00*	17.57	2780	4940	179	4970	3360	3620	6430	239	6640	278	7720	4620	4730	8410	278	7720	323	8970	6720
6	*20.00*	19.64													5690	10120	314	7850	366	9150	7560
* 6	*23.00*	22.81													7180	12770	371	8070	432	9390	8870
6⅝	*20.00*	19.49	2360	4200	195	4880	3040	3060	5440	259	6480	293	7330	4180							
6⅝	*24.00*	23.58						4250	7560	320	6670	370	7710	5110	5550	9870	373	7770	430	8960	7440
6⅝	*28.00*	27.65													7110	12640	443	7910	511	9130	8810
* 6⅝	*32.00*	31.20													8490	15090	506	7910	582	9090	10040
* 7	*17.00*	16.70	1370	2440	160	4710	2310														
7	*20.00*	19.54	1920	3420	191	4770	2720	2500	4440	254	6350			3740							
* 7	*23.00*	22.63						3290	5850	300	6520	344	7480	4360	4300	7640	350	7610	400	8700	6340
7	*26.00*	25.66													5320	9460	402	7730	460	8850	7240
* 7	*29.00*	28.72													6370	11320	454	7830	520	8970	8160
* 7	*32.00*	31.68													7400	13160	505	7890	578	9030	9060

*7	*35.00*	34.58													8420	14970	554	7910	635	9070	9960
*7	*38.00*	37.26													9080	16140	600	7890	688	9050	10800
*7⅝	*24.00*	23.47	1970	3500	227	4730	2750														
7⅝	*26.40*	25.56						3010	5350	333	6310	378	7160	4140	3930	6990	387	7330	439	8310	6020
7⅝	*29.70*	29.04													4910	8730	446	7510	505	8500	6890
7⅝	*33.70*	33.04													6070	10790	513	7610	581	8620	7890
*7⅝	*39.00*	38.05													7530	13390	596	7640	676	8670	9180
8⅝	*28.00*	27.02	1580	2810	252	4500	2470														
8⅝	*32.00*	31.10	2110	3750	295	4610	2860	2740	4870	393	6140	437	6830	3930							
8⅝	*36.00*	35.14						3420	6080	448	6220	499	6930	4460	4470	7950	522	7250	581	8070	6490
*8⅝	*40.00*	39.29													5390	9580	589	7360	655	8190	7300
8⅝	*44.00*	43.39													6320	11240	654	7430	729	8280	8120
*8⅝	*49.00*	48.00													7370	13100	729	7440	812	8290	9040
*9⅝	*32.30*	31.03	1320	2350	279	4320	2270														
9⅝	*36.00*	34.86	1710	3040	318	4420	2560	2220	3950	422	5860	462	6420	3520							
9⅝	*40.00*	38.94						2770	4920	477	5960	521	6510	3950	3530	6280	555	6940	606	7580	5750
9⅝	*43.50*	42.70													4280	7610	614	7060	670	7700	6330
9⅝	*47.00*	46.14													4900	8710	666	7090	727	7730	6870
9⅝	*53.50*	52.85													6110	10860	770	7200	841	7860	7930
*10¾	*32.75*	31.20	710	1260	265	4050	1820														
10¾	*40.50*	38.88	1340	2380	338	4170	2280	1730	3080	450	5560	478	5900	3130							
10¾	*45.50*	44.22						2300	4090	518	5690	550	6040	3580							
10¾	*51.00*	49.50						2870	5100	585	5740	622	6100	4030	3750	6670	680	6670	724	7100	5860
10¾	*55.50*	54.21													4420	7860	750	6760	798	7190	6450
11¾	*42.00*	40.60	940	1670	336	4000	1980														
11¾	*47.00*	45.56						1630	2900	507	5390	526	5600	3070							
11¾	*54.00*	52.57						2270	4040	593	5490	614	5690	3560							
11¾	*60.00*	58.81						2840	5050	668	5570	694	5780	4010	3710	6500	778	6480	807	6720	5830
13⅜	*48.00*	45.98	740	1320	352	3660	1730														
13⅜	*54.50*	52.74						1140	2030	545	5000	545	5000	2730							
13⅜	*61.00*	59.45						1670	2970	613	5030	614	5030	3090							
13⅜	*68.00*	66.11						2140	3800	695	5110	695	5110	3450							
13⅜	*72.00*	70.60													2880	5120	868	6030	868	6030	5380

**See note on page 19.

†Casing of all grades furnished with short threads and couplings. Grades J-55 and N-80 may be supplied with long threads and couplings when so specified on order but subject to wall thickness limitations.

††Setting depth properties are based on API Code 5-C-2 Second Edition, May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse values corresponds to S.F. 1½ on old *averages* and is based on setting depth in salt water at pressure of .5 lb. per foot depth; S.F. 2 on new *minimum* tensile strength of joint values corresponds to S.F. 2½ on old *averages*. For comparison of Safety Factors see Collapse Data Charts on pages P11-12.

**PITTSBURGH SEAMLESS A P I STANDARD ROUND THREAD CASING
Short and Long Threads and Couplings PART II

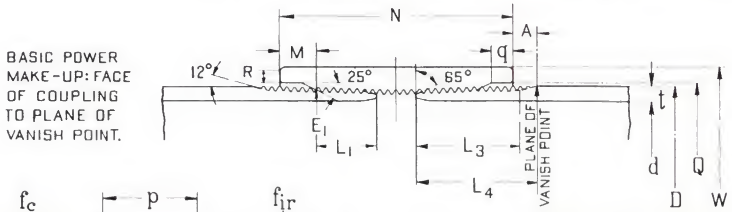
Size—Outside Diameter	Weight Per Foot		Outside Diameter	Inside Diameter	Drift Diameter	Wall Thickness	Area Body of Pipe	D/t Ratio	Internal Test Pressures Per Sq. In.			Internal Test Pressures Per Sq. In.		Coupling			
									Short Threads			Long Threads		Short Threads		Long Threads	
	Nominal Threads and Couplings	Plain End							H-40	J-55	N-80	J-55	N-80	Outside Diameter	Length	Outside Diameter	Length
Ins.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.
*4½	*9.50*	9.40	4.500	4.090	3.965	.205	2.765	21.95	2200	2800	....	....	....	5.000	5	......	....
*4½	*11.60*	11.35	4.500	4.000	3.875	.250	3.338	18.00	....	2800	2800	2800	2800	5.000	5	5.000	7
*4½	*13.50*	13.04	4.500	3.920	3.795	.290	3.835	15.52	....	....	2800	....	2800	5.000	5	5.000	7
*5	*11.50*	11.23	5.000	4.560	4.435	.220	3.304	22.72	....	2800	....	....	....	5.563	6½	......	....
*5	*13.00*	12.83	5.000	4.494	4.369	.253	3.773	19.76	....	2800	....	2800	....	5.563	6½	5.563	7¾
*5	*15.00*	14.87	5.000	4.408	4.283	.296	4.374	16.89	....	2800	2800	2800	2800	5.563	6½	5.563	7¾
*5	*18.00*	17.93	5.000	4.276	4.151	.362	5.274	13.81	....	....	2800	....	2800	5.563	6½	5.563	7¾
5½	*14.00*	13.70	5.500	5.012	4.887	.244	4.028	22.54	2100	2800	....	....	....	6.050	6¾	......	....
*5½	*15.50*	15.35	5.500	4.950	4.825	.275	4.515	20.00	....	2800	....	2800	....	6.050	6¾	6.050	8
5½	*17.00*	16.87	5.500	4.892	4.767	.304	4.962	18.09	....	2800	2800	2800	2800	6.050	6¾	6.050	8
5½	*20.00*	19.81	5.500	4.778	4.653	.361	5.828	15.23	....	....	2800	....	2800	6.050	6¾	6.050	8
*5½	*23.00*	22.54	5.500	4.670	4.545	.415	6.629	13.25	....	....	2800	....	2800	6.050	6¾	6.050	8
6	*18.00*	17.57	6.000	5.424	5.299	.288	5.168	20.83	2300	2800	2800	2800	2800	6.625	7	6.625	8½
6	*20.00*	19.64	6.000	5.352	5.227	.324	5.777	18.52	....	....	2800	....	2800	6.625	7	6.625	8½
*6	*23.00*	22.81	6.000	5.240	5.115	.380	6.709	15.79	....	....	2800	....	2800	6.625	7	6.625	8½
6⅝	*20.00*	19.49	6.625	6.049	5.924	.288	5.734	23.00	2100	2800	....	2800	....	7.390	7¼	7.390	8¾
6⅝	*24.00*	23.58	6.625	5.921	5.796	.352	6.938	18.82	....	2800	2800	2800	2800	7.390	7¼	7.390	8¾
6⅝	*28.00*	27.65	6.625	5.791	5.666	.417	8.133	15.89	....	....	2800	....	2800	7.390	7¼	7.390	8¾
*6⅝	*32.00*	31.20	6.625	5.675	5.550	.475	9.176	13.95	....	....	2800	....	2800	7.390	7¼	7.390	8¾
*7	*17.00*	16.70	7.000	6.538	6.413	.231	4.912	30.30	1600	....	....	....	....	7.656	7¼	......	....
7	*20.00*	19.54	7.000	6.456	6.331	.272	5.744	25.73	1900	2600	....	....	....	7.656	7¼	......	....
*7	*23.00*	22.63	7.000	6.366	6.241	.317	6.656	22.08	....	2800	2800	2800	2800	7.656	7¼	7.656	9
7	*26.00*	25.66	7.000	6.276	6.151	.362	7.550	19.34	....	....	2800	....	2800	7.656	7¼	7.656	9
*7	*29.00*	28.72	7.000	6.184	6.059	.408	8.447	17.16	....	....	2800	....	2800	7.656	7¼	7.656	9

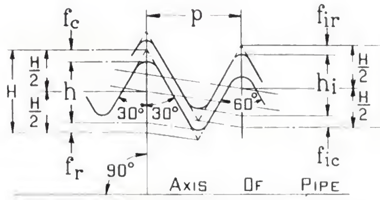
*7	*32.00*	31.68	7.000	6.094	5.969	.453	9.318	15.45	....	....	2800	....	2800	7.656	7¼	7.656	9
*7	*35.00*	34.58	7.000	6.004	5.879	.498	10.170	14.06	....	....	2800	....	2800	7.656	7¼	7.656	9
*7	*38.00*	37.26	7.000	5.920	5.795	.540	10.959	12.96	....	....	2800	....	2800	7.656	7¼	7.656	9
*7⅝	*24.00*	23.47	7.625	7.025	6.900	.300	6.903	25.41	1900	....	....	....	....	8.500	7½	......	....
7⅝	*26.40*	25.56	7.625	6.969	6.844	.328	7.519	23.25	....	2800	2800	2800	2800	8.500	7½	8.500	9¼
7⅝	*29.70*	29.04	7.625	6.875	6.750	.375	8.542	20.33	....	....	2800	....	2800	8.500	7½	8.500	9¼
7⅝	*33.70*	33.04	7.625	6.765	6.640	.430	9.720	17.73	....	....	2800	....	2800	8.500	7½	8.500	9¼
*7⅝	*39.00*	38.05	7.625	6.625	6.500	.500	11.191	15.25	....	....	2800	....	2800	8.500	7½	8.500	9¼
8⅝	*28.00*	27.02	8.625	8.017	7.892	.304	7.947	28.37	1700	....	....	....	....	9.625	7¾	......	....
8⅝	*32.00*	31.10	8.625	7.921	7.796	.352	9.149	24.50	2000	2700	....	2700	....	9.625	7¾	9.625	10
8⅝	*36.00*	35.14	8.625	7.825	7.700	.400	10.336	21.56	....	2800	2800	2800	2800	9.625	7¾	9.625	10
*8⅝	*40.00*	39.29	8.625	7.725	7.600	.450	11.556	19.17	....	....	2800	....	2800	9.625	7¾	9.625	10
8⅝	*44.00*	43.39	8.625	7.625	7.500	.500	12.762	17.25	....	....	2800	....	2800	9.625	7¾	9.625	10
*8⅝	*49.00*	48.00	8.625	7.511	7.386	.557	14.118	15.48	....	....	2800	....	2800	9.625	7¾	9.625	10
*9⅝	*32.30*	31.03	9.625	9.001	8.845	.312	9.128	30.85	1600	....	....	....	....	10.625	7¾	......	....
9⅝	*36.00*	34.86	9.625	8.921	8.765	.352	10.255	27.34	1800	2400	....	2400	....	10.625	7¾	10.625	10½
9⅝	*40.00*	38.94	9.625	8.835	8.679	.395	11.454	24.36	....	2700	2800	2700	2800	10.625	7¾	10.625	10½
9⅝	*43.50*	42.70	9.625	8.755	8.599	.435	12.559	22.13	....	....	2800	....	2800	10.625	7¾	10.625	10½
9⅝	*47.00*	46.14	9.625	8.681	8.525	.472	13.572	20.39	....	....	2800	....	2800	10.625	7¾	10.625	10½
9⅝	*53.50*	52.85	9.625	8.535	8.379	.545	15.547	17.66	....	....	2800	....	2800	10.625	7¾	10.625	10½
*10¾	*32.75*	31.20	10.750	10.192	10.036	.279	9.179	38.53	1200	....	....	....	....	11.750	8	......	....
10¾	*40.50*	38.88	10.750	10.050	9.894	.350	11.436	30.71	1600	2100	....	2100	....	11.750	8	11.750	10½
10¾	*45.50*	44.22	10.750	9.950	9.794	.400	13.007	26.87	....	2500	....	2500	....	11.750	8	11.750	10½
10¾	*51.00*	49.50	10.750	9.850	9.694	.450	14.562	23.89	....	2800	2800	2800	2800	11.750	8	11.750	10½
10¾	*55.50*	54.21	10.750	9.760	9.604	.495	15.948	21.71	....	....	2800	....	2800	11.750	8	11.750	10½
11¾	*42.00*	40.60	11.750	11.084	10.928	.333	11.941	35.28	1400	....	....	....	....	12.750	8	......	....
11¾	*47.00*	45.56	11.750	11.000	10.844	.375	13.401	31.33	....	2100	....	2100	....	12.750	8	12.750	10½
11¾	*54.00*	52.57	11.750	10.880	10.724	.435	15.463	27.01	....	2400	....	2400	....	12.750	8	12.750	10½
11¾	*60.00*	58.81	11.750	10.772	10.616	.489	17.299	24.03	....	2700	2800	2700	2800	12.750	8	12.750	10½
13⅜	*48.00*	45.98	13.375	12.715	12.559	.330	13.524	40.53	1200	....	....	....	....	14.375	8	......	....
13⅜	*54.50*	52.74	13.375	12.615	12.459	.380	15.518	35.20	....	1900	....	1900	....	14.375	8	14.375	10½
13⅜	*61.00*	59.45	13.375	12.515	12.359	.430	17.492	31.10	....	2100	....	2100	....	14.375	8	14.375	10½
13⅜	*68.00*	66.11	13.375	12.415	12.259	.480	19.450	27.86	....	2400	....	2400	....	14.375	8	14.375	10½
13⅜	*72.00*	70.60	13.375	12.347	12.191	.514	20.767	26.02	....	....	2800	....	2800	14.375	8	14.375	10½

**Adopted by the API Committee on the standardization of Oil Country Tubular Goods, November 1940, as tentative and subsequently ratified by letter ballot; adopted as standard by the Committee as of November 1941, and subsequently ratified by letter ballot. New sizes and weights are marked (*); remaining sizes and weights are continued from API Std. No. 5-A, 11th Edition. For data on sizes and weights recently discontinued from API Std. see pages P28B, C, D and E.

PITTSBURGH SEAMLESS API STANDARD ROUND THREAD CASING

Thread Dimensions PART III





TAPER 1 IN 16 ON DIAMETER

(SHOWN EXAGGERATED IN DIAGRAM)

THREAD HEIGHT DIMENSIONS (INCHES)	
THREAD ELEMENT	8-THREADS PER INCH p = .125
H = .866 p	.10825
$h = h_i = .626\,p - .007$	.07125
$f_r = f_{ir} = .120\,p + .002$	.01700
$f_c = f_{ic} = .120\,p + .005$	.02000

Source: API Std. 5A

Outside Diameter	Nominal Weight	Length: End of Pipe to Hand-tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter At Handtight Plane E_1	End of Pipe to Center of Coupling, Made Up J	Diameter of Recess Q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R	Handtight Standoff A
Ins.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Threads
SHORT THREADS AND COUPLINGS										
4½	All	1.055	1.715	2.000	4.41174	.500	4 19/32	.695	5/32	2
5	11.50	1.555	2.215	2.500	4.91174	.750	5 3/32	.695	3/16	2
5	*	1.805	2.465	2.750	4.91174	.500	5 3/32	.695	3/16	2
5½	13.00	1.680	2.340	2.625	5.41174	.750	5 19/32	.695	1/8	2
5½	*	1.930	2.590	2.875	5.41174	.500	5 19/32	.695	1/8	2
6	All	2.055	2.715	3.000	5.91174	.500	6 3/32	.695	3/16	2
6⅝	All	2.180	2.840	3.125	6.53674	.500	6 23/32	.695	1/4	2
7	17.00	1.430	2.090	2.375	6.91174	1.250	7 3/32	.695	3/16	2
7	*	2.180	2.840	3.125	6.91174	.500	7 3/32	.695	3/16	2
7⅝	20.00	1.863	2.590	2.875	7.53255	.875	7 23/32	.700	1/4	2½
7⅝	*	2.238	2.965	3.250	7.53255	.500	7 23/32	.700	1/4	2½
8⅝	24.00	1.988	2.715	3.000	8.53255	.875	8 23/32	.700	9/32	2½
8⅝	*	2.363	3.090	3.375	8.53255	.500	8 23/32	.700	9/32	2½
9⅝	29.30	2.238	2.965	3.250	9.53255	.625	9 23/32	.700	9/32	2½
9⅝	*	2.363	3.090	3.375	9.53255	.500	9 23/32	.700	9/32	2½
10¾	32.75	1.738	2.465	2.750	10.65755	1.250	10 27/32	.700	9/32	2½
10¾	*	2.488	3.215	3.500	10.65755	.500	10 27/32	.700	9/32	2½
11¾	38.00	2.238	2.965	3.250	11.65755	.750	11 27/32	.700	9/32	2½
11¾	*	2.488	3.215	3.500	11.65755	.500	11 27/32	.700	9/32	2½
13⅜	All	2.488	3.215	3.500	13.28255	.500	13 15/32	.700	5/16	2½
LONG THREADS AND COUPLINGS										
4½	All	2.055	2.715	3.000	4.41174	.500	4 19/32	.695	5/32	2
5	All	2.430	3.090	3.375	4.91174	.500	5 3/32	.695	3/16	2
5½	All	2.555	3.215	3.500	5.41174	.500	5 19/32	.695	1/8	2
6	All	2.805	3.465	3.750	5.91174	.500	6 3/32	.695	3/16	2
6⅝	All	2.930	3.590	3.875	6.53674	.500	6 23/32	.695	1/4	2
7	All	3.055	3.715	4.000	6.91174	.500	7 3/32	.695	3/16	2
7⅝	All	3.113	3.840	4.125	7.53255	.500	7 23/32	.700	1/4	2½
8⅝	All	3.488	4.215	4.500	8.53255	.500	8 23/32	.700	9/32	2½
9⅝	All	3.738	4.465	4.750	9.53255	.500	9 23/32	.700	9/32	2½
10¾	All	3.738	4.465	4.750	10.65755	.500	10 27/32	.700	9/32	2½
11¾	All	3.738	4.465	4.750	11.65755	.500	11 27/32	.700	9/32	2½
13⅜	All	3.738	4.465	4.750	13.28255	.500	13 15/32	.700	5/16	2½

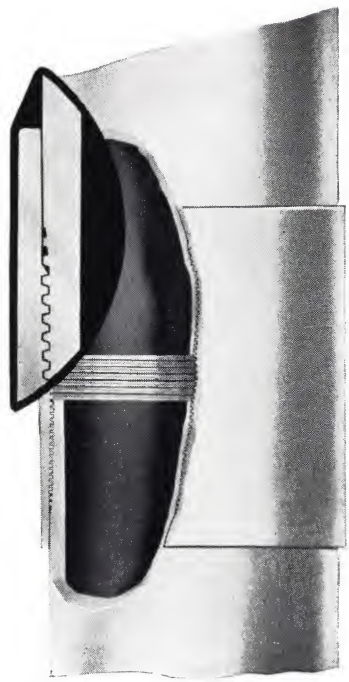
Depth of Recess "q" is ½ inch on all sizes of Short and Long Thread Couplings.

*All remaining weights in these sizes respectively.

Pittsburgh Special

ACME-THREAD CASING

Patent No. 1,942,518



Double Seal Joint. An extra and effective shoulder seal provided by this machined *land* area on pipe and mating recess in coupling, *tapered* in exact alignment with the threads.

Conventional Assembly. An improved fast-running casing joint, six-pitch Acme-type threads and extra clearance coupling, that follows familiar manufacturing methods and that fits in perfectly with *customary* field practice.

Pittsburgh Special Acme-Thread Casing incorporates a combination of improvements which add to the certainty of getting to bottom safely. The features of this Casing include:

1. Extra seal, support and protection to last engaged thread provided by land-and-counterbore gripping shoulder.

2. Greater joint strength in thread design, resisting pull-out.

3. Quick, foolproof stabbing and quick spinning-in effect fast make-up and fast running. Reduces running time more than one-half. (Acme-type six-pitch threads).

4. Extra clearance of thin-wall alloy-steel coupling minimizes danger of hanging up.

5. Sturdy Acme-type threaded joint will make-up and break repeatedly without galling or other injury to threads.

**PITTSBURGH SPECIAL ACME-THREAD CASING

With Thin Wall Extra-Clearance Coupling and Quick-Spinning, Fast-Running, Six-Pitch Threads

Size—Outside Diameter	Weight Per Foot		GRADE J-55					GRADE N-80					Outside Diameter	Inside Diameter	Drift Diameter	Wall Thickness	Area Body of Pipe	D/t Ratio	Internal Test Pressures Per Sq. In.		Coupling	
	Nominal Threads and Couplings	Plain End	Collapsing Pressures		Min. Tensile Strength of Joint		Internal Pressure at Min. Yield Strength P.S.I.	Collapsing Pressures		Min. Tensile Strength of Joint		Internal Pressure at Min. Yield Strength P.S.I.							J-55	N-80	Outside Diameter	Length
			Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2		Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2											
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.		Lbs.	Lbs.	Ins.	Ins.
*4½	*11.60*	11.35	4540	8070	177	7620	5350	5930	10540	193	8345	7780	4.500	4.000	3.875	.250	3.338	18.00	2800	2800	5.000	7⅝
*4½	*13.50*	13.04	....	....	...	.....	....	7350	13070	239	8860	9020	4.500	3.920	3.795	.290	3.835	15.52	....	2800	5.000	7⅝
*5	*13.00*	12.83	3930	6990	202	7750	4870	....	.....	...	.....	.....	5.000	4.494	4.369	.253	3.773	19.76	2800	....	5.375	7⅝
*5	*15.00*	14.87	4980	8850	252	8400	5700	6520	11590	276	9200	8290	5.000	4.408	4.283	.296	4.374	16.89	2800	2800	5.375	7⅝
*5	*18.00*	17.93	....	....	...	.....	....	8550	15200	359	9970	10140	5.000	4.276	4.151	.362	5.274	13.81	....	2800	5.375	7⅝
*5½	*15.50*	15.35	3860	6860	252	8133	4810	....	.....	...	.....	.....	5.500	4.950	4.825	.275	4.515	20.00	2800	....	5.875	8
5½	*17.00*	16.87	4500	8000	290	8520	5320	5890	10470	318	9340	7740	5.500	4.892	4.767	.304	4.962	18.09	2800	2800	5.875	8
5½	*20.00*	19.81	....	....	...	.....	....	7580	13480	397	9930	9190	5.500	4.778	4.653	.361	5.828	15.23	....	2800	5.875	8
*5½	*23.00*	22.54	....	....	...	.....	....	8900	15820	470	10230	10560	5.500	4.670	4.545	.415	6.629	13.25	....	2800	5.875	8
6	*18.00*	17.57	3620	6430	295	8200	4620	4730	8410	323	8980	6720	6.000	5.424	5.299	.288	5.168	20.83	2800	2800	6.400	8¼
6	*20.00*	19.64	....	....	...	.....	....	5690	10120	379	9490	7560	6.000	5.352	5.227	.324	5.777	18.52	....	2800	6.400	8¼
*6	*23.00*	22.81	....	....	...	.....	....	7180	12770	465	10110	8870	6.000	5.240	5.115	.380	6.709	15.79	....	2800	6.500	8¼
6⅝	*20.00*	19.49	3060	5440	328	8202	4180	....	.....	...	.....	.....	6.625	6.049	5.924	.288	5.734	23.00	2800	....	7.000	8½
6⅝	*24.00*	23.58	4250	7560	430	8940	5110	5550	9870	470	9790	7440	6.625	5.921	5.796	.352	6.938	18.82	2800	2800	7.000	8½
6⅝	*28.00*	27.65	....	....	...	.....	....	7110	12640	580	10360	8810	6.625	5.791	5.666	.417	8.133	15.89	....	2800	7.250	8½
*6⅝	*32.00*	31.20	....	....	...	.....	....	8490	15090	676	10560	10040	6.625	5.675	5.550	.475	9.176	13.95	....	2800	7.250	8½

*7	*23.00*	22.63	3290	5850	397	8620	4360	4300	7640	435	9450	6340	7.000	6.366	6.241	.317	6.656	22.08	2800	2800	7.400	8½
7	*26.00*	25.66	....	....	....	....	....	5320	9460	517	9940	7240	7.000	6.276	6.151	.362	7.550	19.34	....	2800	7.400	8½
*7	*29.00*	28.72	....	....	....	....	....	6370	11320	600	10340	8160	7.000	6.184	6.059	.408	8.447	17.16	....	2800	7.600	8½
*7	*32.00*	31.68	....	....	....	....	....	7400	13160	679	10620	9060	7.000	6.094	5.969	.453	9.318	15.45	....	2800	7.600	8½
*7	*35.00*	34.58	....	....	....	....	....	8420	14970	758	10830	9960	7.000	6.004	5.879	.498	10.170	14.06	....	2800	7.750	8½
*7	*38.00*	37.26	....	....	....	....	....	9080	16140	831	10930	10800	7.000	5.920	5.795	.540	10.959	12.96	....	2800	7.750	8½
7⅝	*26.40*	25.56	3010	5350	454	8610	4140	3930	6990	498	9430	6020	7.625	6.969	6.844	.328	7.519	23.25	2800	2800	8.250	9
7⅝	*29.70*	29.04	....	....	....	....	....	4910	8730	592	9970	6890	7.625	6.875	6.750	.375	8.542	20.33	....	2800	8.250	9
7⅝	*33.70*	33.04	....	....	....	....	....	6070	10790	700	10390	7890	7.625	6.765	6.640	.430	9.720	17.73	....	2800	8.250	9
*7⅝	*39.00*	38.05	....	....	....	....	....	7530	13390	836	10720	9180	7.625	6.625	6.500	.500	11.191	15.25	....	2800	8.250	9
8⅝	*32.00*	31.10	2740	4870	568	8870	3930	....	....	....	....	....	8.625	7.921	7.796	.352	9.149	24.50	2700	....	9.200	9½
8⅝	*36.00*	35.14	3420	6080	668	9270	4460	4470	7950	731	10160	6490	8.625	7.825	7.700	.400	10.336	21.56	2800	2800	9.200	9½
*8⅝	*40.00*	39.29	....	....	....	....	....	5390	9590	844	10550	7300	8.625	7.725	7.600	.450	11.556	19.17	....	2800	9.200	9½
8⅝	*44.00*	43.39	....	....	....	....	....	6320	11240	955	10850	8120	8.625	7.625	7.500	.500	12.762	17.25	....	2800	9.400	9½
*8⅝	*49.00*	48.00	....	....	....	....	....	7370	13110	1079	11010	9040	8.625	7.511	7.386	.557	14.118	15.48	....	2800	9.400	9½
9⅝	*36.00*	34.86	2220	3950	637	8850	3520	....	....	....	....	....	9.625	8.921	8.765	.352	10.255	27.34	2400	....	10.250	10
9⅝	*40.00*	38.94	2770	4920	738	9230	3950	3530	6280	809	10110	5750	9.625	8.835	8.679	.395	11.454	24.36	2700	2800	10.250	10
9⅝	*43.50*	42.70	....	....	....	....	....	4280	7610	910	10460	6330	9.625	8.755	8.599	.435	12.559	22.13	....	2800	10.250	10
9⅝	*47.00*	46.14	....	....	....	....	....	4900	8710	1003	10540	6870	9.625	8.681	8.525	.472	13.572	20.39	....	2800	10.250	10
9⅝	*53.50*	52.85	....	....	....	....	....	6110	10860	1185	10930	7930	9.625	8.535	8.379	.545	15.547	17.66	....	2800	10.400	10

**These sizes and weights correspond to the API Revised Casing List (May 1942—See page P19). New sizes and weights are marked (*); remaining sizes and weights are continued from old list. For data on discontinued sizes and weights see page P28A.

Setting depth properties are based on API Code 5-C-2 Second Edition, May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse corresponds to S.F. 1½ on old *averages* and is based on setting depth in salt water at pressure of .5 lb. per foot depth; S.F. 2 on new *minimum* tensile strength of joint values corresponds to S.F. 2½ on old *averages*. For comparison of Safety Factors see Collapse Data Charts on pages P11-12.

**PITTSBURGH SPECIAL ACME-THREAD CASING—INTERNAL UPSET

With Thin Wall Extra Clearance Coupling and Quick-Spinning, Fast-Running, Six-Pitch Threads—100% Joint Efficiency

Size—Outside Diameter	Weight Per Foot		GRADE J-55					GRADE N-80					Outside Diameters	Inside Diameters	Wall Thickness	Area Body of Pipe	D/t Ratio	Internal Test Pressures Per Sq. In.		Upset		Coupling	
			Collapsing Pressures		†Min. Tensile Strength of Joint			Collapsing Pressures		†Min. Tensile Strength of Joint													
	Nominal Threads and Couplings	Plain End	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.						J-55	N-80	Inside Diameter	Length	Outside Diameter	Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Ins.	Ins.	Ins.	Sq. Ins.		Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.
*4½	*11.60*	11.35	4540	8070	290	12520	5350	5930	10540	307	13240	7780	4.500	4.000	.250	3.338	18.00	2800	2800	3.799	4¹⁄₁₆	5.000	7⅝
*4½	*13.50*	13.04	....	....	...	.....	....	7350	13070	322	11930	9020	4.500	3.920	.290	3.835	15.52	....	2800	3.714	4¹⁄₁₆	5.000	7⅝
*5	*13.00*	12.83	3930	6990	317	12190	4870	....	.....	....	.....	.....	5.000	4.494	.253	3.773	19.76	2800	....	4.295	4¹⁄₁₆	5.375	7⅝
*5	*15.00*	14.87	4980	8850	367	12250	5700	6520	11590	402	13410	8290	5.000	4.408	.296	4.374	16.89	2800	2800	4.205	4¹⁄₁₆	5.375	7⅝
*5	*18.00*	17.93	....	....	...	.....	....	8550	15200	486	13480	10140	5.000	4.276	.362	5.274	13.81	....	2800	4.066	4¹⁄₁₆	5.563	7⅝
*5½	*15.50*	15.35	3860	6860	379	12230	4810	....	.....	....	.....	.....	5.500	4.950	.275	4.515	20.00	2800	....	4.751	4¼	5.875	8
5½	*17.00*	16.87	4500	8000	417	12260	5320	5890	10470	457	13430	7740	5.500	4.892	.304	4.962	18.09	2800	2800	4.691	4¼	5.875	8
5½	*20.00*	19.81	....	....	...	.....	....	7580	13480	536	13400	9190	5.500	4.778	.361	5.828	15.23	....	2800	4.572	4¼	6.050	8
*5½	*23.00*	22.54	....	....	...	.....	....	8900	15820	610	13260	10560	5.500	4.670	.415	6.629	13.25	....	2800	4.459	4¼	6.050	8
6	*18.00*	17.57	3620	6430	434	9650	4620	4730	8410	475	10570	6720	6.000	5.424	.288	5.168	20.83	2800	2800	5.226	4⅜	6.500	8¼
6	*20.00*	19.64	....	....	...	.....	....	5690	10120	531	10630	7560	6.000	5.352	.324	5.777	18.52	....	2800	5.151	4⅜	6.500	8¼
*6	*23.00*	22.81	....	....	...	.....	....	7180	12770	617	13420	8870	6.000	5.240	.380	6.709	15.79	....	2800	5.035	4⅜	6.500	8¼
6⅝	*20.00*	19.49	3060	5440	482	12040	4180	....	.....	....	.....	.....	6.625	6.049	.288	5.734	23.00	2800	....	5.853	4½	7.000	8½
6⅝	*24.00*	23.58	4250	7560	582	12140	5110	5550	9870	638	13300	7440	6.625	5.921	.352	6.938	18.82	2800	2800	5.720	4½	7.250	8½
6⅝	*28.00*	27.65	....	....	...	.....	....	7110	12640	748	13360	8810	6.625	5.791	.417	8.133	15.89	....	2800	5.586	4½	7.250	8½
*6⅝	*32.00*	31.20	....	....	...	.....	....	8490	15090	844	13190	10040	6.625	5.675	.475	9.176	13.95	....	2800	5.466	4½	7.250	8½

*7	*23.00*	22.63	3290	5850	559	12150	4360	4300	7640	612	13300	6340	7.000	6.366	.317	6.656	22.08	2800	2800	6.170	4½	7.400	8½
7	*26.00*	25.66	....	....	...	.....	....	5320	9460	694	13360	7240	7.000	6.276	.362	7.550	19.34	....	2800	6.076	4½	7.600	8½
*7	*29.00*	28.72	....	....	...	.....	....	6370	11320	777	13400	8160	7.000	6.184	.408	8.447	17.16	....	2800	5.982	4½	7.600	8½
*7	*32.00*	31.68	....	....	...	.....	....	7400	13160	857	13390	9060	7.000	6.094	.453	9.318	15.45	....	2800	5.889	4½	7.750	8½
*7	*35.00*	34.58	....	....	...	.....	....	8420	14970	936	13370	9960	7.000	6.004	.498	10.170	14.06	....	2800	5.796	4½	7.750	8½
*7	*38.00*	37.26	....	....	...	.....	....	9080	16140	1008	13270	10800	7.000	5.920	.540	10.959	12.96	....	2800	5.709	4½	7.750	8½
7⅝	*26.40*	25.56	3010	5350	632	11960	4140	3930	6990	692	13100	6020	7.625	6.969	.328	7.519	23.25	2800	2800	6.774	4¾	8.250	9
7⅝	*29.70*	29.04	....	....	...	.....	....	4910	8730	786	13230	6890	7.625	6.875	.375	8.542	20.33	....	2800	6.677	4¾	8.250	9
7⅝	*33.70*	33.04	....	....	...	.....	....	6070	10790	894	13270	7890	7.625	6.765	.430	9.720	17.73	....	2800	6.563	4¾	8.250	9
*7⅝	*39.00*	38.05	....	....	...	.....	....	7530	13390	1030	13200	9180	7.625	6.625	.500	11.191	15.25	....	2800	6.419	4¾	8.250	9
8⅝	*32.00*	31.10	2740	4870	769	12010	3930	....	.....	....	.....	.....	8.625	7.921	.352	9.149	24.50	2700	....	7.726	5	9.200	9½
8⅝	*36.00*	35.14	3420	6080	868	12060	4460	4470	7950	951	13210	6490	8.625	7.825	.400	10.336	21.56	2800	2800	7.628	5	9.200	9½
*8⅝	*40.00*	39.29	....	....	...	.....	....	5390	9590	1063	13290	7300	8.625	7.725	.450	11.556	19.17	....	2800	7.526	5	9.400	9½
8⅝	*44.00*	43.39	....	....	...	.....	....	6320	11240	1174	13340	8120	8.625	7.625	.500	12.762	17.25	....	2800	7.423	5	9.400	9½
*8⅝	*49.00*	48.00	....	....	...	.....	....	7370	13110	1299	13250	9040	8.625	7.511	.557	14.118	15.48	....	2800	7.306	5	9.400	9½
9⅝	*36.00*	34.86	2220	3950	861	11960	3520	....	.....	....	.....	.....	9.625	8.921	.352	10.255	27.34	2400	....	8.728	5¼	10.250	10
9⅝	*40.00*	38.94	2770	4920	962	12030	3950	3530	6280	1054	13170	5750	9.625	8.835	.395	11.454	24.36	2700	2800	8.640	5¼	10.250	10
9⅝	*43.50*	42.70	....	....	...	.....	....	4280	7610	1155	13280	6330	9.625	8.755	.435	12.559	22.13	....	2800	8.558	5¼	10.250	10
9⅝	*47.00*	46.14	....	....	...	.....	....	4900	8710	1249	13280	6870	9.625	8.681	.472	13.572	20.39	....	2800	8.483	5¼	10.250	10
9⅝	*53.50*	52.85	....	....	...	.....	....	6110	10860	1430	13370	7930	9.625	8.535	.545	15.547	17.66	....	2800	8.333	5¼	10.400	10

**These sizes and weights correspond to the API Revised Casing List (May 1942—See page P19). New sizes and weights are marked (*); remaining sizes and weights are continued from old list. For data on discontinued sizes and weights see page P28A.

Setting depth properties are based on API Code 5-C-2 Second Edition May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse corresponds to S.F. 1½ on old *averages* and is based on setting depth in salt water at pressure of .5 lb. per foot depth; S.F. 2 on new *minimum* tensile strength of joint values corresponds to S.F. 2½ on old *averages*.

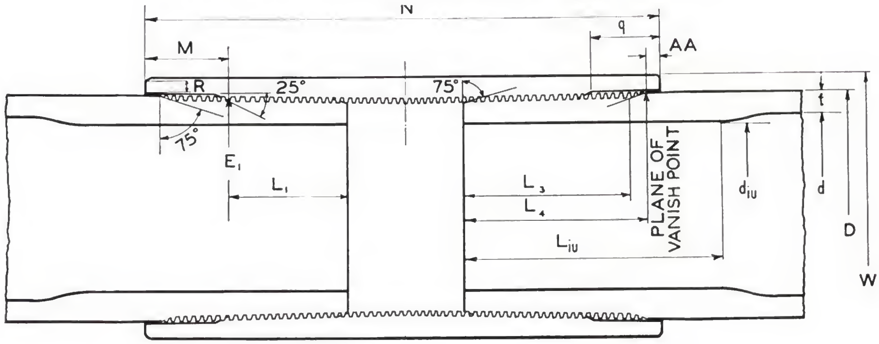
†Joint strength values of the internal upset casing are equal to the body strength of the pipe (joint is 100% efficient).

For comparison of Safety Factors see Collapse Data Charts on pages P11-12.

PITTSBURGH SPECIAL ACME-THREAD CASING

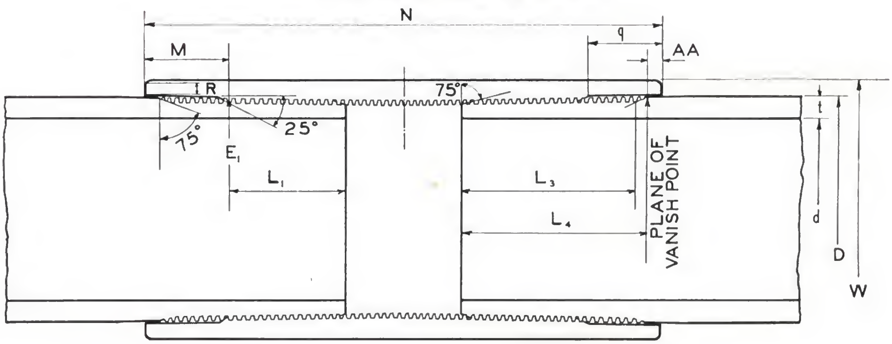
Thread Dimensions

INTERNAL UPSET—DOUBLE SEAL JOINT

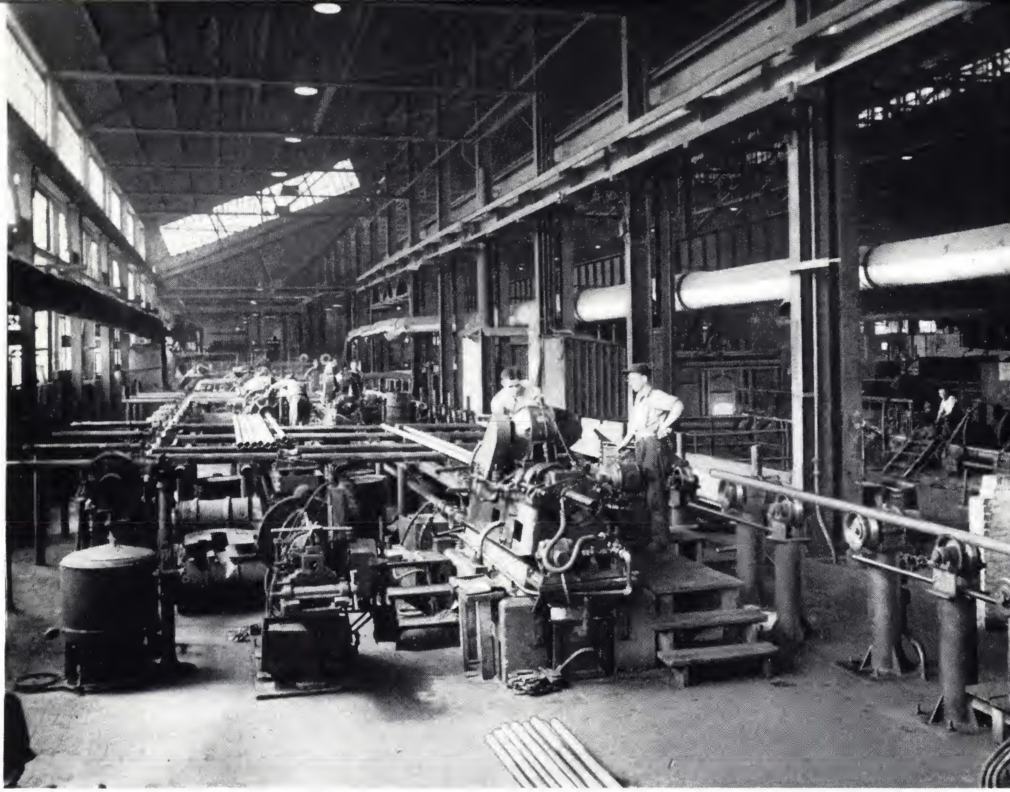


EXTRA CLEARANCE—DOUBLE SEAL JOINT

TYPICAL SECTION OF JOINT



Outside Diameter	Length: End of Pipe to Handtight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Depth of Recess q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R	Face of Coupling to Vanish Point Handtight
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
4½	1.044	1.731	2.000	4.373	1.125	1.206	5/32	.250
5	1.606	2.293	2.562	4.873	1.125	1.206	5/32	.250
5½	1.794	2.481	2.750	5.373	1.125	1.206	5/32	.250
6	1.919	2.606	2.875	5.873	1.125	1.206	5/32	.250
6⅝	2.044	2.731	3.000	6.498	1.125	1.206	⅛	.250
7	2.044	2.731	3.000	6.873	1.125	1.206	⅛	.250
7⅝	2.294	2.981	3.250	7.498	1.125	1.206	¼	.250
8⅝	2.544	3.231	3.500	8.498	1.125	1.206	3/16	.250
9⅝	2.794	3.481	3.750	9.498	1.125	1.206	9/32	.250

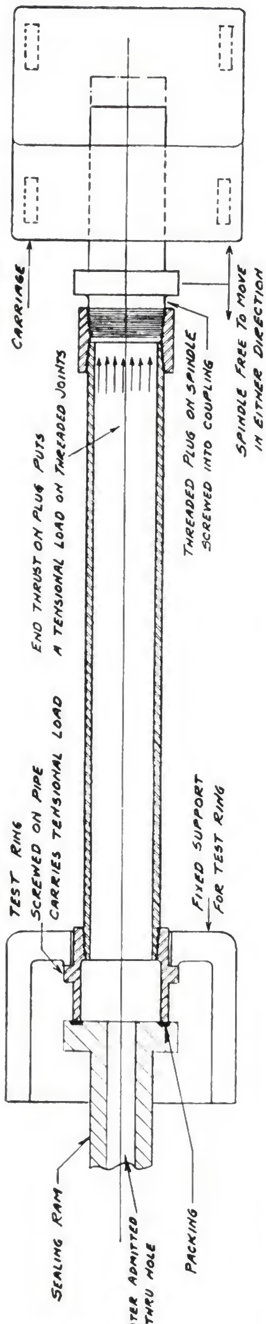


Oil Well tubing layout includes end heating, upsetting, normalizing, threading, coupling application, testing and stenciling.

General view of Pilger Mill.

Pittsburgh

HYDROSTATIC TENSION TESTING



A New Method of Hydrostatic Testing at the Mill that Matches Field Conditions

The old or standard mill practice for hydrostatic testing of threaded and coupled casing is to *compress* the pipe at the ends with sealing heads. This puts a column stress on the threads and casing body, which is obviously an incorrect condition under which to test the pipe and coupling assembly because when the casing is actually put into service, it is always *in tension*. When the pipe is under compression the tapered form of the threaded pipe end and threaded area of the coupling exaggerate unnaturally the sealing effect of the joint; when the same joint is put in tension not only are the bearing faces of the threads reversed, but the reverse of the taper effect imposes a more severe condition upon the joint under which it may develop leaks that would not be detected with the pipe under compression.

The standard mill practice of hydrostatic testing of casing under compression has been under criticism for some time because of the "leakers" that have shown up in the field in casing so tested. In order to make hydrostatic testing at the mill more valid our engineers have developed a new method of making hydrostatic tests in which the pipe and coupling assembly are in tension, thus comparing with field conditions. Our equipment for this new testing method has been so designed that the testing can be conducted almost as rapidly as the old conventional method, and the new method is now applied as standard to all Pittsburgh Seamless Casing.

Under the "Pittsburgh" Hydrostatic Tension Testing method, the coupling end of the casing joint is sealed with a threaded plug applied to the exposed threaded area of the coupling. The power mechanism which quickly inserts this plug is mounted in a floating carriage which, being free to move away from the end of the pipe, avoids placing any compression or column stress on the pipe. A special threaded collar is applied to the threaded field end of the pipe; this special collar is sealed in the hydrostatic pressure mechanism whereupon the pipe is filled with water and the test pressure applied.

It will be seen from the diagrams here that this method allows the internal pressure being applied to act in tension on the area of plug in the coupling end. In the case of 7″ O.D. casing, for example, the area of this plug is 33.6 square inches and with the standard test pressure of 2800 pounds per square inch employed in testing Grade N-80 material, the total tension load amounts to 105,560 pounds.

During a series of tests following the installation of this equipment, comparing hydrostatic tension testing with the old method, it was demonstrated that the new method would find "leakers" that would not show up under the old method of hydrostatic testing.

This new hydrostatic tension testing method is used for all current mill production of Pittsburgh Seamless Casing. All casing so tested is stenciled "Pittsburgh Hydrostatic Tension Tested."

*PITTSBURGH SPECIAL ACME-THREAD CASING

With Thin Wall Extra Clearance Coupling and Quick-Spinning, Fast-Running, Six-Pitch Threads

Size—Outside Diameter	Weight Per Foot		GRADE J-55					GRADE N-80					Outside Diameters	Inside Diameters	Wall Thickness	Area Body of Pipe	D/t Ratio	Upset		Internal Test Pressures Per Sq. In.		Coupling		Drift Diameter
			Collapsing Pressure		†Minimum Strength of Joint			Collapsing Pressure		†Minimum Strength of Joint														
	Nominal Threads and Couplings	Plain Ends	Minimum P.S.I.	†Equiv. Length S.F. 1⅛	†1000 Pounds	†Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.	Minimum P.S.I.	†Equiv. Length S.F. 1⅛	†1000 Pounds	†Equiv. Length S.F. 2	Internal Pressure at Min. Yield Strength P.S.I.						Inside Diameter "ND"	Length "M"	J-55	N-80	Outside Diameter	Length	
Ins.	Lbs.	Lbs.	Lbs.	Lbs.		Ft.	Lbs.	Lbs.	Lbs.		Ft.	Lbs.	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Lbs.	Lbs.	Ins.	Ins.	
PITTSBURGH SPECIAL ACME-THREAD CASING (NOT UPSET)																								
6⅝	*26.00*	25.658	4850	8620	481	9240	5590	6350	11290	526	10120	8140	6.625	5.855	.385	7.548	17.21	.....	...	2800	2800	7.000	8½	5.730
7	*24.00*	23.643	3550	6310	422	8790	4570	4640	8250	462	9630	6640	7.000	6.336	.332	6.955	21.08	.....	...	2800	2800	7.400	8½	6.211
7	*28.00*	27.731	4610	8200	522	9340	5400	6030	10720	573	10230	7860	7.000	6.214	.393	8.158	17.81	.....	...	2800	2800	7.400	8½	6.089
7	*30.00*	29.712	5130	9120	572	9530	5820	6710	11930	626	10440	8460	7.000	6.154	.423	8.741	16.55	.....	...	2800	2800	7.400	8½	6.029
8⅝	*38.00*	37.220	3770	6700	719	9460	4740	4930	8760	787	19360	6900	8.625	7.775	.425	10.949	20.29	.....	...	2800	2800	9.200	9½	7.650
8⅝	*43.00*	42.327	4650	8270	846	9830	5430	6080	10810	926	10770	7900	8.625	7.651	.487	12.451	17.71	.....	...	2800	2800	9.200	9½	7.526
PITTSBURGH SPECIAL ACME-THREAD CASING (INTERNAL UPSET) 100% JOINT EFFICIENCY																								
6⅝	*26.00*	25.658	4850	8620	634	12190	5590	6350	11290	694	13350	8140	6.625	5.855	.385	7.548	17.21	5.652	4½	2800	2800	7.250	8½	.....
7	*24.00*	23.643	3550	6310	584	12170	4570	4640	8250	640	13330	6640	7.000	6.336	.332	6.955	21.08	6.138	4½	2800	2800	7.400	8½	.....
7	*28.00*	27.731	4610	8200	686	12240	5400	6030	10720	750	13400	7860	7.000	6.214	.393	8.158	17.81	6.012	4½	2800	2800	7.600	8½	.....
7	*30.00*	29.712	5130	9120	734	12240	5820	6710	11930	804	13400	8460	7.000	6.154	.423	8.741	16.55	5.951	4½	2800	2800	7.600	8½	.....
8⅝	*38.00*	37.220	3770	6700	920	12100	4740	4930	8760	1007	13250	6900	8.625	7.775	.425	10.949	20.29	7.577	5	2800	2800	9.200	9½	.....
8⅝	*43.00*	42.327	4650	8270	1046	12160	5430	6080	10810	1146	13320	7900	8.625	7.651	.487	12.451	17.71	7.449	5	2800	2800	9.400	9½	.....

*These tables show information on the former sizes and weights of Pittsburgh Steel Acme-Thread Casing which are discontinued with the adoption of the Revised Casing List sizes and weights shown on pages P22-25.

Setting depth properties are based on API Code 5-C-2 Second Edition May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse values corresponds to S.F. 1½ on old *averages* and are based on setting depth in salt water at pressure of .5 lb. per ft. depth; S.F. 2 on new minimum joint strength values corresponds to S.F. 2½ on old *averages*.

†Joint strength values of the internal upset casing are equal to the body strength of the pipe (joint is 100% efficient.)

PITTSBURGH SEAMLESS A P I 8 ROUND THREAD CASING

*(**DISCONTINUED FROM A P I STD.)*

Short Threads and Couplings

Size—Outside Diameter	Weight Per Foot: Nominal Threads and Couplings	Weight Per Foot: Plain End	GRADE H-40 Collapsing Pressures: Minimum P.S.I.	GRADE H-40 Collapsing Pressures: Equiv. Length S.F. $1\frac{1}{8}$	GRADE H-40 Av. Ultimate Strength of Joint: 1000 Pounds	GRADE H-40 Av. Ultimate Strength of Joint: Equiv. Length S.F. 2	GRADE H-40 Internal Pressure at Min. Yield Strength P.S.I.	GRADE J-55 Collapsing Pressures: Minimum P.S.I.	GRADE J-55 Collapsing Pressures: Equiv. Length S.F. $1\frac{1}{8}$	GRADE J-55 Av. Ultimate Strength of Joint: 1000 Pounds	GRADE J-55 Av. Ultimate Strength of Joint: Equiv. Length S.F. 2	GRADE J-55 Internal Pressure at Min. Yield Strength P.S.I.	Internal Test Pressures Per Sq. In.: H-40	Internal Test Pressures Per Sq. In.: J-55	Outside Diameter	Inside Diameter	Drift Diameter	Wall Thickness	Area Body of Pipe	D/t Ratio	Coupling: Outside Diameter	Coupling: Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.		Ins.	Ins.
4¾	*16.00*	15.75	....	....	....	....	....	6340	11270	226	7060	6760	....	2800	4.750	4.082	3.957	.344	4.634	14.22	5.364	6¼
5½	*15.00*	14.71	2770	4920	151	5030	3340	3590	6380	201	6700	4600	2300	2800	5.500	4.974	4.849	.263	4.327	20.91	6.050	6¾
5½	*17.00*	16.87	3470	6170	176	5170	3870	....	....	....	....	....	2700	....	5.500	4.892	4.767	.304	4.962	18.09	6.050	6¾
5½	*20.00*	19.81	....	....	....	....	....	5770	10260	280	7000	6320		2800	5.500	4.778	4.653	.361	5.828	15.23	6.050	6¾
**5¾*	*17.00*	16.36	....	....	....	....	....	3710	6600	223	6570	4690	....	2800	5.750	5.190	5.065	.280	4.811	20.53	6.420	7
**5¾*	*19.50*	19.10	....	....	....	....	....	4760	8460	266	6810	5520	....	2800	5.750	5.090	4.965	.330	5.619	17.42	6.420	7
**5¾*	*22.50*	21.79	....	....	....	....	....	5850	10400	307	6830	6360	....	2800	5.750	4.990	4.865	.380	6.411	15.13	6.420	7
6	*16.00*	15.35	....	....	....	....	....	2840	5050	205	6400	4010	....	2700	6.000	5.500	5.375	.250	4.516	24.00	6.625	7
6	*20.00*	19.64	....	....	....	....	....	4350	7730	270	6750	5200	....	2800	6.000	5.352	5.227	.324	5.777	18.52	6.625	7
6⅝	*26.00*	25.66	....	....	....	....	....	4850	8620	351	6750	5590	....	2800	6.625	5.855	5.730	.385	7.548	17.21	7.390	7¼
6⅝	*28.00*	27.65	....	....	....	....	....	5440	9670	381	6800	6060	....	2800	6.625	5.791	5.666	.417	8.133	15.89	7.390	7¼
**6⅝*	*29.00*	28.57	....	....	....	....	....	5720	10170	395	6810	6270	....	2800	6.625	5.761	5.636	.432	8.405	15.34	7.390	7¼

7	*22.00*	21.54	2310	4110	214	4860	3010	3010	5350	284	6450	4140	2100	2800	7.000	6.398	6.273	.301	6.335	23.25	7.656	7¼
7	*24.00*	23.64	2730	4850	237	4940	3320	3550	6310	315	6560	4570	2300	2800	7.000	6.336	6.211	.332	6.955	21.08	7.656	7¼
7	*26.00*	25.66	3130	5660	259	4980	3620	4070	7240	345	6630	4980	2500	2800	7.000	6.276	6.151	.362	7.550	19.34	7.656	7¼
7	*28.00*	27.73	.....	.....	.....	.....	.....	4610	8200	375	6690	5400	.....	2800	7.000	6.214	6.089	.393	8.158	17.81	7.656	7¼
7	*30.00*	29.71	.....	.....	.....	.....	.....	5130	9120	405	6750	5820	.....	2800	7.000	6.154	6.029	.423	8.741	16.55	7.656	7¼
7⅝	*29.70*	29.04	.....	.....	.....	.....	.....	3760	6684	382	6430	4730	.....	2800	7.625	6.875	6.750	.375	8.542	20.33	8.500	7½
7⅝	*33.70*	33.04	.....	.....	.....	.....	.....	4640	8250	440	6530	5430	.....	2800	7.625	6.765	6.640	.430	9.720	17.73	8.500	7½
8⅝	*28.00*	27.02	.....	.....	.....	.....	.....	2060	3660	336	6000	3400	.....	2300	8.625	8.017	7.892	.304	7.947	28.37	9.625	7¾
8⅝	*38.00*	37.22	.....	.....	.....	.....	.....	3770	6700	477	6270	4740	.....	2800	8.625	7.775	7.650	.425	10.949	20.29	9.625	7¾
8⅝	*43.00*	42.33	.....	.....	.....	.....	.....	4650	8270	548	6370	5430	.....	2800	8.625	7.651	7.526	.487	12.451	17.71	9.625	7¾
9	*34.00*	32.78	.....	.....	.....	.....	.....	2570	4570	408	6000	3800	.....	2600	9.000	8.290	8.134	.355	9.641	25.35	10.000	7¾
9	*38.00*	36.91	.....	.....	.....	.....	.....	3210	5710	464	6100	4300	.....	2800	9.000	8.196	8.040	.402	10.859	22.39	10.000	7¾
9	*40.00*	38.92	.....	.....	.....	.....	.....	3520	6260	492	6150	4540	.....	2800	9.000	8.150	7.994	.425	11.440	21.18	10.000	7¾
9	*45.00*	44.02	.....	.....	.....	.....	.....	4320	7680	562	6240	5170	.....	2800	9.000	8.032	7.876	.484	12.949	18.59	10.000	7¾
*9⅝	*38.00*	36.95	.....	.....	.....	.....	.....	2500	4440	450	5930	3740	.....	2600	9.625	8.877	8.721	.374	10.869	25.73	10.625	7¾
9⅝	*43.50*	42.70	.....	.....	.....	.....	.....	3270	5810	527	6050	4350	.....	2800	9.625	8.755	8.599	.435	12.559	22.13	10.625	7¾
10¾	*55.50*	54.21	.....	.....	.....	.....	.....	3380	6010	C44	5800	4430	.....	2800	10.750	9.760	9.604	.495	15.948	21.72	11.750	8
13⅜	*48.00*	45.98	.....	.....	.....	.....	.....	740	1320	469	4880	2370	.....	1600	13.375	12.715	12.559	.330	13.529	40.53	14.375	8

*Non API Sizes.

**Sizes and weights in this table are those discontinued from API Standard 5-A 11th Edition with the adoption of the Revised Casing List by the API Committee on the Standardization of Oil Country Tubular Goods, November 1941. Data on the remaining sizes and weights of the former casing list in API Std. 5-A 11th Ed. are shown in the Revised Casing List on pages P16-19.

Setting depth properties are based on API Code 5-C-2 Second Edition May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse values corresponds to S.F. 1½ on old *averages* and is based on setting depth in salt water at pressure of .5 pound per foot depth; S.F. 2 on new *minimum* joint strength values corresponds to S.F. 2½ on old *averages*.

PITTSBURGH SEAMLESS A P I 8 ROUND THREAD CASING

*(**DISCONTINUED FROM A P I STD.)*

Long Threads and Couplings

Size—Outside Diameter	Weight Per Foot: Nominal Threads and Couplings	Weight Per Foot: Plain End	Grade J-55: Collapsing Pressures: Minimum P.S.I.	Grade J-55: Collapsing Pressures: Equiv. Length S.F. 1⅛	Grade J-55: Av. Ultimate Strength of Joint: 1000 Pounds	Grade J-55: Av. Ultimate Strength of Joint: Equiv. Length S.F. 2	Grade J-55: Internal Pressure at Min. Yield Strength P.S.I.	Grade N-80: Collapsing Pressures: Minimum P.S.I.	Grade N-80: Collapsing Pressures: Equiv. Length S.F. 1⅛	Grade N-80: Av. Ultimate Strength of Joint: 1000 Pounds	Grade N-80: Av. Ultimate Strength of Joint: Equiv. Length S.F. 2	Grade N-80: Internal Pressure at Min. Yield Strength P.S.I.	Internal Test Pressures Per Sq. In.: J-55	Internal Test Pressures Per Sq. In.: N-80	Outside Diameter	Inside Diameter	Drift Diameter	Wall Thickness	Area Body of Pipe	D/t Ratio	Coupling: Outside Diameter	Coupling: Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.	Sq. Ins.		Ins.	Ins.
4¾	*16.00*	15.75	6340	11270	269	8400	6760	8330	14800	312	9750	9840	2800	2800	4.750	4.082	3.957	.334	4.634	14.22	5.364	7½
**5¾*	*17.00*	16.36	3710	6600	261	7680	4690	4840	8600	304	8930	6820	2800	2800	5.750	5.190	5.065	.280	4.811	20.53	6.420	8¼
**5¾*	*19.50*	19.10	4760	8460	310	7960	5520	6220	11070	362	9260	8030	2800	2800	5.750	5.090	4.965	.330	5.619	17.42	6.420	8¼
**5¾*	*22.50*	21.79	5850	10400	359	7980	6360	7570	13480	418	9280	9250	2800	2800	5.750	4.990	4.865	.380	6.411	15.13	6.420	8¼
6	*20.00*	19.64	4350	7730	315	7870	5200	....	....	....	....	....	2800	....	6.000	5.352	5.227	.324	5.777	18.52	6.625	8½
6⅝	*20.00*	19.49	....	....	....	....	....	4010	7130	348	8700	6080	....	2800	6.625	6.049	5.924	.288	5.734	23.00	7.390	8¾
6⅝	*26.00*	25.66	4850	8620	405	7790	5590	6350	11290	471	9060	8140	2800	2800	6.625	5.855	5.730	.385	7.548	17.21	7.390	8¾
6⅝	*28.00*	27.65	5440	9670	439	7840	6060	....	....	....	....	....	2800	....	6.625	5.791	5.666	.417	8.133	15.89	7.390	8¾
6⅝	*29.00*	28.57	5720	10170	455	7840	6270	7470	13280	530	9140	9130	2800	2800	6.625	5.761	5.636	.432	8.405	15.33	7.390	8¾
7	*22.00*	21.54	3010	5350	326	7410	4140	3930	6980	379	8610	6020	2800	2800	7.000	6.398	6.273	.301	6.335	23.25	7.656	9
7	*24.00*	23.64	3550	6310	362	7540	4570	4640	8250	420	8750	6640	2800	2800	7.000	6.336	6.211	.332	6.955	21.08	7.656	9
7	*26.00*	25.66	4070	7230	395	7590	4980	....	....	....	....	....	2800	....	7.000	6.276	6.151	.362	7.550	19.34	7.656	9
7	*28.00*	27.73	4610	8200	430	7680	5400	6030	10720	501	8940	7860	2800	2800	7.000	6.214	6.089	.393	8.158	17.81	7.656	9
7	*30.00*	29.71	5130	9120	464	7730	5820	6710	11930	539	8980	8460	2800	2800	7.000	6.154	6.029	.423	8.741	16.55	7.656	9

7⅝	*29.70*	29.04	3760	6680	434	7300	4730	.....	.....	.....	.....	.....	2800	.....	7.625	6.875	6.750	.375	8.542	20.33	8.500	9¼
7⅝	*33.70*	33.04	4640	8250	499	7400	5430	.....	.....	.....	.....	.....	2800	.....	7.625	6.765	6.640	.430	9.720	17.73	8.500	9¼
8⅝	*32.00*	31.10	.....	.....	.....	.....	.....	3470	6170	509	7950	5710	.....	2800	8.625	7.921	7.796	.352	9.149	24.50	9.625	10
8⅝	*38.00*	37.22	3770	6700	531	6980	4740	4930	8760	618	8130	6900	2800	2800	8.625	7.775	7.650	.425	10.949	20.29	9.625	10
8⅝	*43.00*	42.33	4650	8270	610	7090	5430	6080	10810	710	8250	7900	2800	2800	8.625	7.651	7.526	.487	12.451	17.71	9.625	10
8⅝	*44.00*	43.39	4830	8590	626	7110	5580	.....	.....	.....	.....	.....	2800	.....	8.625	7.625	7.500	.500	12.762	17.25	9.625	10
9	*34.00*	32.78	2570	4570	451	6630	3800	3120	5550	525	7720	5520	2600	2800	9.000	8.290	8.134	.355	9.641	25.35	10.000	10¼
9	*38.00*	36.91	3210	5700	514	6760	4300	4190	7450	598	7870	6250	2800	2800	9.000	8.196	8.040	.402	10.859	22.39	10.000	10¼
9	*40.00*	38.92	3520	6260	544	6800	4540	4610	8200	633	7910	6610	2800	2800	9.000	8.150	7.994	.425	11.449	21.18	10.000	10¼
9	*45.00*	44.02	4320	7680	621	6900	5170	5650	10040	722	8020	7530	2800	2800	9.000	8.032	7.876	.484	12.949	18.59	10.000	10¼
9	*55.00*	53.33	5810	10330	761	6920	6350	7580	13480	886	8050	9240	2800	2800	9.000	7.812	7.656	.594	15.687	15.15	10.000	10¼
9⅝	*36.00*	34.86	.....	.....	.....	.....	.....	2480	4430	537	7460	5120	.....	2800	9.625	8.921	8.765	.352	10.255	27.34	10.625	10½
**9⅝*	*38.00*	36.95	2500	4440	492	6470	3740	2990	5320	572	7530	5440	2600	2800	9.625	8.877	8.721	.374	10.869	25.73	10.625	10½
9⅝	*43.50*	42.70	3270	5810	575	6610	4350	.....	.....	.....	.....	.....	2800	.....	9.625	8.755	8.599	.435	12.559	22.13	10.625	10½
9⅝	*47.00*	46.14	3740	6650	626	6660	4720	.....	.....	.....	.....	.....	2800	.....	9.625	8.681	8.525	.472	13.572	20.39	10.625	10½
9⅝	*53.50*	52.85	4670	8300	722	6750	5450	.....	.....	.....	.....	.....	2800	.....	9.625	8.535	8.379	.545	15.547	17.66	10.625	10½
10¾	*40.50*	38.88	.....	.....	.....	.....	.....	1730	3080	557	6870	4560	.....	2800	10.750	10.050	9.894	.350	11.436	30.71	11.750	10½
10¾	*45.50*	44.22	.....	.....	.....	.....	.....	2610	4640	641	7040	5210	.....	2800	10.750	9.950	9.794	.400	13.007	26.87	11.750	10½
10¾	*55.50*	54.21	3380	6000	686	6180	4430	.....	.....	.....	.....	.....	2800	.....	10.750	9.760	9.604	.495	15.948	21.71	11.750	10½
11¾	*47.00*	45.56	.....	.....	.....	.....	.....	1630	2900	613	6520	4460	.....	2800	11.750	11.000	10.844	.375	13.401	31.33	12.750	10½
11¾	*54.00*	52.57	.....	.....	.....	.....	.....	2570	4570	715	6620	5180	.....	2800	11.750	10.880	10.724	.435	15.463	27.01	12.750	10½
13⅜	*61.00*	59.45	.....	.....	.....	.....	.....	1670	2970	714	5850	4500	.....	2800	13.375	12.515	12.359	.430	17.492	31.10	14.375	10½
13⅜	*68.00*	66.11	.....	.....	.....	.....	.....	2330	4140	800	5880	5020	.....	2800	13.375	12.415	12.259	.480	19.450	27.86	14.375	10½
13⅜	*72.00*	70.60	2450	4360	738	5120	3700	.....	.....	.....	.....	.....	2500	.....	13.375	12.347	12.191	.514	20.767	26.02	14.375	10½
13⅜	*83.00*	81.86	3230	5740	863	5200	4310	4230	7520	1000	6020	6280	2800	2800	13.375	12.175	12.019	.600	24.080	22.29	14.375	10½

*Non API Sizes.

**Sizes and weights in this table are those discontinued from API Standard 5-A 11th Edition with the adoption of the Revised Casing List by the API Committee on the Standardization of Oil Country Tubular Goods, November 1941. Data on the remaining sizes and weights of the former casing list in API Std. 5-A 11th Ed. are shown in the Revised Casing List on pages P16-P19.

Setting depth properties are based on API Code 5-C-2 Second Edition May 1942. We do not recommend any factors of safety nor guarantee setting depths. Such data given here as matter of information only: S.F. 1⅛ on new *minimum* collapse values corresponds to S.F. 1½ on old *averages* and is based on setting depth in salt water at pressure of .5 pound per foot depth; S.F. 2 on new *minimum* joint strength values corresponds to S.F. 2½ on old *averages*.

THE PROPER APPLICATION OF TOOL JOINTS

The correct application of tool joints to A P I and Pittsburgh Special drill pipe is of great importance because the full strength of any joint is obtained only by proper make-up procedure, including correct lubrication and the accurate control of torque load and r.p.m. Because of the importance of correct tool joint application, well equipped field shops have been established in every active field, and all joints should be made up in such a first class field shop rather than on the derrick floor.

The bucking-up specifications given here apply equally to A P I drill pipe and tool joints, and Pittsburgh Special drill pipe and tool joints, except for the special specifications indicated as referring to the Pittsburgh Special assembly. The full advantage of the plus values of Pittsburgh Special drill pipe and corresponding tool joints can only be obtained by their proper application.

BUCKING-UP SPECIFICATIONS

Tool Joints With Either A P I or Pittsburgh Special Pipe Ends.†

1. Threads on pipe shall be washed with kerosene, brushed thoroughly with wire brush to remove all grease, grit, loose scale and other foreign particles, then blown practically dry with air.
2. Pipe threads in tool joints, which are furnished with thread protectors in the pipe ends, shall be carefully examined and need not be washed, provided they are found to be properly coated with clean zinc base lubricant. Otherwise, the pipe threads in the tool joints shall also be cleaned as specified above. (Pittsburgh Special): check inner edge of recess of tool joint for burrs or dents caused by handling and remove these before tool joint is put on pipe.
3. Palubco or similar zinc base lubricant, not less than 50% to 60% zinc base, applied with a seam brush or similar hairbrush shall be used as thread dope. Sufficient dope to color entire thread of tool joint only is usually ample. The amount of thread dope necessary will vary with the temperature of the work. Chattering may indicate insufficient lubricant or not sufficient zinc content, while low torque usually results from an excess. (Pittsburgh Special): A mixture of 50% white lead and 50% tallow shall be applied to the plain tapered portion of the pipe.
4. The joints shall be run on the pipe "hand tight," this term signifying the degree of tightness obtained by "spinning" the joint by means of two wraps of ¾" rope, one man pulling, the other taking up the slack.
5. From the "hand tight" position, the joint shall be made up a total machine draw of not less than three turns. The speed of bucking up shall not exceed 2 r.p.m. (Pittsburgh Special); it is intended that the tool joint shall draw at least one thread from "hand tight" position before the Pittsburgh Special tapered counterbore contacts with the land area on the pipe. At least two additional threads draw is desired after this point is reached.
6. Joints shall be bucked on by power until the torque developed lies within the limits tabulated, with the added provision that the final standoff, scratch to scratch, shall not be less than one thread. (Table 1.)
7. Joints which do not meet these specifications shall be removed from the pipe and replaced by other joints.

Table 1

TOOL JOINTS WITH REGULAR A P I OR PITTSBURGH SPECIAL PIPE ENDS

*Nominal Size of Drill Pipe—Inches	Bucking-Up Torque: Maximum Foot-Lbs.	Bucking-Up Torque: Minimum Foot-Lbs.
2⅜"	6,000	3,500
2⅞"	9,000	5,500
3½"	14,000	8,000
4½"	17,000	12,000
5 9/16"	21,000	15,000
6⅝"	23,000	16,500

*Data apply to all weights of Grade "D" drill pipe.

†*NOTE:* Leading tool joint manufacturers who have been licensed to make special tool joints for Pittsburgh Special Drill Pipe carry stocks at their plants and field shops. Bucking-up may be done there or in any properly equipped shop. Pittsburgh Steel Company also carries stocks of tool joints at its Allenport, Pennsylvania, Works, where it has all facilities for proper tool joint application.

Pittsburgh Special
DRILL PIPE

Pittsburgh Special Internal Upset Drill Pipe and Mating Tool Joint.

Rotary drilling subjects the drill stem to constant vibration. There is a bending or "weaving" motion which—in the case of usual pipe joints—is concentrated approximately at the end-turns of the threads, causing the outer turns of the joint threads to bite into the pipe ends and break them off. Most break-offs occur at this point. Shoulder-welding of tool joint and pipe to help this condition introduces dangerous distortion of grain structure and warpage.

Pittsburgh Special Drill Pipe eliminates these serious hazards of hard drilling. It affords all the advantages of shoulder-welding without the disadvantages. The tight-fitting shoulder and the 35% or more added contact surface relieve the last engaged threads on the pipe of destructive vibrations, whipping and "biting," and seal the joint against abrasive sands, salt water and sulphur water. The pipe is available either Internal Upset or External Upset. Internal Flush.

Pittsburgh Special Drill Pipe is available with either right or left hand threads. Since size and form of threads, taper and pipe size are standard, corresponding with A P I, it is entirely practical to make up Pittsburgh Special Drill Pipe or corresponding special tool joints with regular A P I pipe or tool joints although the full advantages of Pittsburgh Special pipe are realized only when it is used with the special tool joints available from tool joint manufacturers who have been licensed to make them.

INTERNAL FLUSH DRILL PIPE

The marked trend favoring internal flush drill pipe and tool joints finds Pittsburgh Special Internal Flush Drill Pipe already a favorite with many prominent producers and drilling contractors. The importance of effective shoulder seal is increased with external upset pipe. Also, in conformance with best drilling experience, the brunt of the wear from side wall contact is taken by a conventional type tool joint which is larger in outside diameter than the largest diameter of the pipe. The dimensions and physical characteristics of the tool joint are designed to withstand this wear.

The use of internal flush drill pipe permits decreased pump pressures of from 25% to 40%, with resultant savings in fuel, boiler equipment and wear and tear on pumping units. It permits the use of larger core barrels and facilitates coring. The descending mud has a free passageway and more readily washes away the cuttings from the bit area, flushing the bit with sufficient force left to bring the cuttings effectively to the surface.

Pittsburgh Special External Upset Internal Flush Drill Pipe. Also Available Without Pittsburgh Special Shoulder Seal.

INTERNAL UPSET OR EXTERNAL UPSET, INTERNAL FLUSH

The Drill Pipe with Plus Features

Pittsburgh Special Drill Pipe has regular A P I thread lengths	PLUS	an accurately machined "land" area in line with the thread taper for the patented Pittsburgh Special Shoulder Seal.
Pittsburgh Special Drill Pipe has regular A P I threading that will make up with A P I tool joints or couplings of the same size	PLUS	at least 35% greater contact surface, affording increased strength and effective shoulder seal when properly made up with corresponding tool joints.
Pittsburgh Special Drill Pipe is made in the regular grades and sizes of A P I Drill Pipe, with standard upset strength	PLUS	the added strength afforded by the shoulder seal contact area, and the certainty of thread accuracy necessary with this type of joint.

PITTSBURGH SPECIAL DRILL PIPE

Internal Upset and External Upset

Size—Outside Diameter	WEIGHT PER FOOT			†GRADE "C"					†GRADE "D"					†GRADE "E"				
	Threads and Couplings	Internal Upset and Threads Only	External Upset and Threads Only	COLLAPSING PRESSURES Minimum P.S.I.	COLLAPSING PRESSURES Equiv. Length S.F. 1⅛	TENSION Load at Minimum Yield	TENSION Equiv. Length	Internal Pressure at Min. Yield Strength	COLLAPSING PRESSURES Minimum P.S.I.	COLLAPSING PRESSURES Equiv. Length S.F. 1⅛	TENSION Load at Minimum Yield	TENSION Equiv. Length	Internal Pressure at Min. Yield Strength	COLLAPSING PRESSURES Minimum P.S.I.	COLLAPSING PRESSURES Equiv. Length S.F. 1⅛	TENSION Load at Minimum Yield	TENSION Equiv. Length	Internal Pressure at Min. Yield Strength
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.
2⅜	6.65	6.32	6.34	7960	14150	82.9	12470	9280	10140	18030	101	15240	11350	12480	22190	138	20780	15470
2⅞	10.40	9.79	9.82	8420	14970	129	12370	9910	10730	19080	157	15110	12120	13210	23480	214	20610	16530
3½	13.30	12.38	12.40	7200	12800	163	12250	8280	9170	16300	199	14970	10120	11290	20070	272	20420	13800
3½	15.50	14.63	14.68	8550	15200	194	12500	10110	10900	19380	237	15270	12350	13420	23860	323	20820	16840
4	14.00	13.26	13.27	5790	10290	171	12230	6500	7380	13120	209	14950	7940	9080	16140	285	20380	10830
4	15.70	14.98	14.99	6580	11700	195	12390	7480	8380	14900	238	15140	9140	10320	18350	324	20640	12470
4½	16.60	15.44	15.35	5300	9420	198	11950	5900	6760	12020	242	14600	7210	8310	14770	331	19910	9830
$5\frac{9}{16}$	22.20	20.14	20.01	4300	7640	259	11680	4990	5480	9740	317	14280	6090	6740	11980	432	19470	8300
$5\frac{9}{16}$	25.25	23.44	23.17	5280	9390	302	11960	5870	6730	11960	369	14620	7180	8290	14740	503	19940	9790
6⅝	25.20	22.77	22.69	3010	5350	294	11650	3920	3840	6830	359	14240	4800	4720	8390	489	19420	6540
							See Note Below					See Note Below					See Note Below	

†We do not recommend any factor of safety nor guarantee setting depths. Such data given here as a matter of information only: S.F. 1⅛ on new minimum collapse values corresponds to S.F. 1½ on old averages and is based on setting depth in salt water at pressure of .5 lb. per foot depth.

Setting depth properties are based on minimum values (75% of old averages.)

Tension load properties are based on the weight of the pipe only; tool joints, drill collars and other variables have not been considered.

PITTSBURGH SPECIAL DRILL PIPE

Internal Upset and External Upset

Size—Outside Diameter	WEIGHT PER FOOT		Wall Thickness	DIAMETERS		INTERNAL UPSET				EXTERNAL UPSET			COUPLINGS			TOOL JOINT	COUPLING WEIGHT (Calculated)	
	Threads and Couplings	Plain Ends		Outside	Inside	Total Length	Inside Diameter at End	Inside Diameter of Full Upset	Length of Taper	**Total Length	Min. Length of Taper	External Upset	Internal Upset / Outside Diameter	External Upset / Outside Diameter	Length	External Upset / Outside Diameter	Internal Upset	External Upset
Ins.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs.
2⅜	*6.65*	6.26	.280	2.375	1.815	3.250	1.375	1.125	1½	4.000	2½	2.787	3.125	3.375	7¾	3.375	7.68	8.00
2⅞	*10.40*	9.72	.362	2.875	2.151	3.500	1.563	1.188	1½	4.500	2½	3.349	3.750	4.125	8¾	4.125	12.28	14.10
3½	*13.30*	12.31	.368	3.500	2.764	3.500	2.375	1.875	1½	4.500	2½	3.955	4.250	4.625	8¾	4.750	12.60	14.50
3½	*15.50*	14.63	.449	3.500	2.602	3.500	2.250	1.750	1½	4.500	2½	3.955	4.250	4.625	8¾	4.750	12.60	14.50
4	*14.00*	12.93	.330	4.000	3.340	4.500	2.625	2.375	2	5.250	2½	4.631	5.000	5.500	*	5.750	21.70	25.20
4	*15.70*	14.69	.380	4.000	3.240	4.500	2.500	2.250	2	5.250	2½	4.631	5.000	5.500	*	5.750	21.70	25.20
4½	*16.60*	14.98	.337	4.500	3.826	5.000	3.031	2.813	2	5.250	2½	5.131	5.500	6.000	10¼	6.125	25.20	27.70
$5\frac{9}{16}$	*22.20*	19.59	.352	5.563	4.859	5.000	4.156	3.813	2	5.500	2½	6.193	6.750	7.375	10¾	7.375	38.20	45.87
$5\frac{9}{16}$	*25.25*	22.82	.415	5.563	4.733	5.000	3.875	3.500	2	5.500	2½	6.193	6.750	7.375	10¾	7.375	38.20	45.87
6⅝	*25.20*	22.19	.330	6.625	5.965	5.000	5.344	5.000	2	5.750	2½	7.255	7.750	8.500	11¼	8.500	44.90	58.50

Test Pressures: Grade "C" 2500 lbs. per square inch for all sizes except $5\frac{9}{16}$" x 22.20 lb. and 6⅝" x 25.20 lb. which are 2400 and 1900 lbs. respectively. Grade "D" 2800 lbs. for all sizes except 6⅝" x 25.20 lb. which is 2500 lbs. Grade "E" 2800 lbs. for all sizes.

*Internal Upset 9½". External Upset 10¼".

**This dimension varies within manufacturing tolerances, but the distance from the last scratch on the pipe to a point the last vestige of the upset merges with the body of the pipe will not be more than 5½" and the distance from the last scratch to the end of the full O.D. of the upset will not be less than 1⅞".

PITTSBURGH SEAMLESS A P I STANDARD DRILL PIPE

Internal Upset and *External Upset

Size—Outside Diameter	WEIGHT PER FOOT			†GRADE "C"					†GRADE "D"					†GRADE "E"				
				COLLAPSING PRESSURES		TENSION			COLLAPSING PRESSURES		TENSION			COLLAPSING PRESSURES		TENSION		
	Threads and Couplings	Internal Upset and Threads Only	External Upset and Threads Only	Minimum P.S.I.	Equiv. Length S.F. $1\frac{1}{8}$	Load at Minimum Yield	Equiv. Length	Internal Pressure at Min. Yield Strength	Minimum P.S.I.	Equiv. Length S.F. $1\frac{1}{8}$	Load at Minimum Yield	Equiv. Length	Internal Pressure at Min. Yield Strength	Minimum P.S.I.	Equiv. Length S.F. $1\frac{1}{8}$	Load at Minimum Yield	Equiv. Length	Internal Pressure at Min. Yield Strength
Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.	Lbs.	Ft.	1000 Lbs.	Ft.	Lbs.
$2\frac{3}{8}$	*6.65*	6.31	6.34	7960	14150	82.9	12470	9280	10140	18030	101	15240	11350	12480	22190	138	20780	15470
$2\frac{7}{8}$	*10.40*	9.78	9.82	8420	14970	129	12370	9910	10730	19080	157	15110	12120	13210	23480	214	20610	16530
$3\frac{1}{2}$	*13.30*	12.36	12.40	7200	12800	163	12250	8280	9170	16300	199	14970	10120	11290	20070	272	20420	13800
$3\frac{1}{2}$	*15.50*	14.68	14.69	8550	15200	194	12500	10110	10900	19380	237	15270	12350	13420	23860	323	20820	16840
‡4	*14.00*	13.24	13.27	5790	10290	171	12230	6500	7380	13120	209	14950	7940	9080	16140	285	20380	10830
‡4	*15.70*	14.96	14.99	6580	11700	195	12390	7480	8380	14900	238	15140	9140	10320	18350	324	20640	12470
$4\frac{1}{2}$	*16.60*	15.42	15.35	5300	9420	198	11950	5900	6760	12020	242	14600	7210	8310	14770	331	19910	9830
$5\frac{9}{16}$	*22.20*	20.10	20.01	4300	7640	259	11680	4990	5480	9740	317	14280	6090	6740	11980	432	19470	8300
$5\frac{9}{16}$	*25.25*	23.41	23.17	5280	9390	302	11960	5870	6730	11960	369	14620	7180	8290	14740	503	19940	9790
$6\frac{5}{8}$	*25.20*	22.72	22.70	3010	5350	294	11650	3920	3840	6830	359	14240	4800	4720	8390	489	19420	6540
							See Note Below					See Note Below					See Note Below	

*Tentative as of November, 1940.

‡Internal Upset Non-A P I Sizes. Published as a matter of information.

†We do not recommend any factor of safety nor guarantee setting depths. Such data given here as a matter of information only: S.F. $1\frac{1}{8}$ on new minimum collapse values corresponds to S.F. $1\frac{1}{2}$ on old averages and is based on setting depth in salt water at pressure of .5 lb. per foot depth. Setting depth properties are based on minimum values (75% of old averages.)

Tension load properties are based on the weight of the pipe only; tool joints, drill collars and other variables have not been considered.

PITTSBURGH SEAMLESS A P I STANDARD DRILL PIPE

Internal Upset and *External Upset

Size—Outside Diameter	WEIGHT PER FOOT		Wall Thickness	DIAMETERS			INTERNAL UPSET				EXTERNAL UPSET			COUPLINGS			TOOL JOINT	COUPLING WEIGHT (Calculated)	
											TOTAL LENGTH								
	Threads and Couplings	Plain Ends		Outside	Inside	External Upset	Total Length	Inside Diameter at End	Inside Diameter of Full Upset	Length of Taper	Maximum	Minimum	Min. Length of Taper	Internal Upset — Outside Diameter	External Upset — Outside Diameter	Length	External Upset — Outside Diameter	Internal Upset	External Upset
Ins.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs.
2⅜	*6.65*	6.26	.280	2.375	1.815	2.656	3.250	1.375	1.125	1½	5.125	4.125	2½	3.125	3.375	5½	3.375	5.64	5.97
2⅞	*10.40*	9.72	.362	2.875	2.151	3.219	3.500	1.563	1.188	1½	5.625	4.625	2½	3.750	4.125	6½	4.125	9.41	10.78
3½	*13.30*	12.31	.368	3.500	2.764	3.824	3.500	2.375	1.875	1½	5.625	4.625	2½	4.250	4.625	6½	4.750	9.67	11.17
3½	*15.50*	14.63	.449	3.500	2.602	3.824	3.500	2.250	1.750	1½	5.625	4.625	2½	4.250	4.625	6½	4.750	9.67	11.17
‡4	*14.00*	12.93	.330	4.000	3.340	4.500	4.500	2.625	2.375	2	6.375	5.375	2½	5.000	5.500	8	5.750	16.32	20.27
‡4	*15.70*	14.69	.380	4.000	3.240	4.500	4.500	2.500	2.250	2	6.375	5.375	2½	5.000	5.500	8	5.750	16.32	20.27
4½	*16.60*	14.98	.337	4.500	3.826	5.000	5.000	3.031	2.813	2	6.375	5.375	2½	5.500	6.000	8	6.125	20.27	22.34
5 9/16	*22.20*	19.59	.352	5.563	4.859	6.063	5.000	4.156	3.813	2	6.625	5.625	2½	6.750	7.375	8½	7.375	31.10	37.12
5 9/16	*25.25*	22.82	.415	5.563	4.733	6.063	5.000	3.875	3.500	2	6.625	5.625	2½	6.750	7.375	8½	7.375	31.10	37.12
6⅝	*25.20*	22.19	.330	6.625	5.965	7.125	5.000	5.344	5.000	2	6.875	5.875	2½	7.750	8.500	9	8.500	37.00	47.99

*Tentative as of November, 1940.

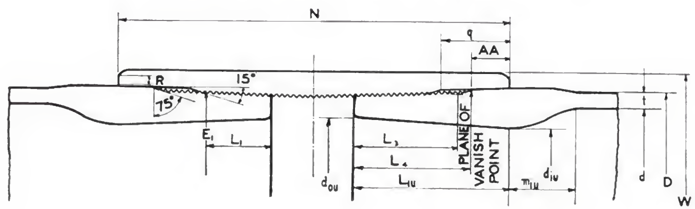
‡Internal Upset Non-A P I Sizes. Published as a matter of information.

Test Pressures: Grade "C" 2500 lbs. per square inch for all sizes except 5 9/16" x 22.20 lb. and 6⅝" x 25.20 lb. which are 2400 and 1900 lbs. respectively. Grade "D" 2800 lbs. for all sizes except 6⅝" x 25.20 lb. which is 2500 lbs. Grade "E" 2800 lbs. for all sizes.

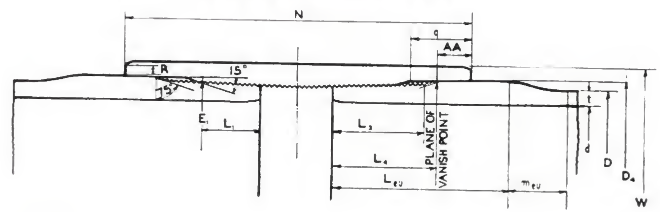
PITTSBURGH SPECIAL DRILL PIPE

Thread Dimensions

INTERNAL UPSET—DOUBLE GRIP JOINT



EXTERNAL UPSET—INTERNAL FLUSH DOUBLE GRIP JOINT



INTERNAL UPSET

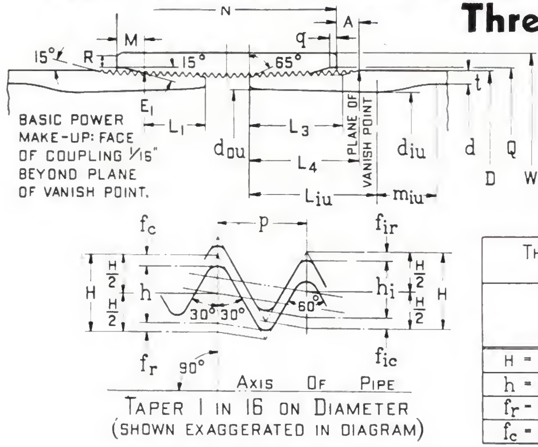
Outside Diameter	Length: End of Pipe to Hand-tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Depth of Recess q	Width of Bearing Face R	Face of Coupling to Vanish Point, Hand-tight AA	Machine Tight
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2 3/8	1.216	1.889	2.125	2.28067	1.5625	5/32	.8125	1.1875
2 7/8	1.716	2.389	2.625	2.78067	1.5625	3/16	.8125	1.1875
3 1/2	1.716	2.389	2.625	3.40567	1.5625	1/4	.8125	1.1875
4	2.091	2.764	3.000	3.90567	1.5625	1/4	.8125	1.1875
4 1/2	2.466	3.139	3.375	4.40567	1.5625	1/4	.8125	1.1875
5 9/16	2.716	3.389	3.625	5.46867	1.5625	1/4	.8125	1.1875
6 5/8	2.966	3.639	3.875	6.53067	1.5625	5/16	.8125	1.1875

EXTERNAL UPSET

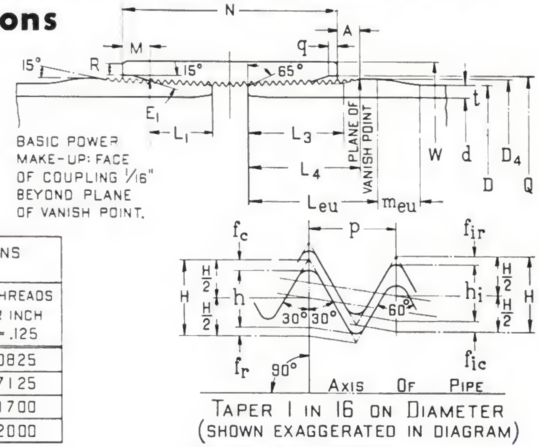
Outside Diameter	Length: End of Pipe to Hand-tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Depth of Recess q	Width of Bearing Face R	Face of Coupling to Vanish Point, Hand-tight AA	Machine Tight
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2 3/8	1.216	1.889	2.125	2.56167	1.5625	5/32	.8125	1.1875
2 7/8	1.716	2.389	2.625	3.12467	1.5625	3/16	.8125	1.1875
3 1/2	1.716	2.389	2.625	3.72967	1.5625	1/4	.8125	1.1875
4	2.466	3.139	3.375	4.40567	1.5625	1/4	.8125	1.1875
4 1/2	2.466	3.139	3.375	4.90567	1.5625	1/4	.8125	1.1875
5 9/16	2.716	3.389	3.625	5.96867	1.5625	1/4	.8125	1.1875
6 5/8	2.966	3.639	3.875	7.03067	1.5625	5/16	.8125	1.1875

PITTSBURGH SEAMLESS A P I STANDARD DRILL PIPE

Thread Dimensions



THREAD HEIGHT DIMENSIONS (INCHES)	
THREAD ELEMENT	8-THREADS PER INCH p = .125
H = .866 p	.10825
h = h_i = .626 p −.007	.07125
f_r = f_{ir} = .120 p +.002	.01700
f_c = f_{ic} = .120 p +.005	.02000



INTERNAL UPSET

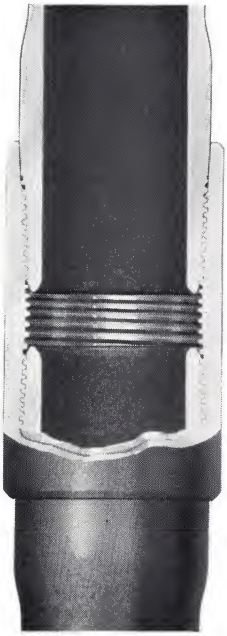
Outside Diameter	Length: End of Pipe to Hand-tight Plane	Effective Length	Total Length: End of Pipe to Vanish Point	Pitch Diameter at Handtight Plane	End of Pipe to Center of Coupling, Made Up	Diameter of Recess	Length: Face of Coupling to Handtight Plane	Width of Bearing Face
	L_1	L_3	L_4	E_1	J	Q	M	R
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2 3/8	1.216	1.889	2.125	2.28067	.5625	2.500	.534	5/32
2 7/8	1.716	2.389	2.625	2.78067	.5625	3.000	.534	3/16
3 1/2	1.716	2.389	2.625	3.40567	.5625	3.625	.534	1/4
*4	2.091	2.764	3.000	3.90567	.5625	4.125	.534	1/4
4 1/2	2.466	3.139	3.375	4.40567	.5625	4.625	.534	1/4
5 9/16	2.716	3.389	3.625	5.46867	.5625	5.6875	.534	1/4
6 5/8	2.966	3.639	3.875	6.53067	.5625	6.750	.534	5/16

*Non-API Sizes. Published as a matter of information. Depth of Recess "q" is 1/8" on all sizes. Handtight standoff "A" is 3 threads on all sizes. Included taper is 0.0625" per inch on all sizes.

*EXTERNAL UPSET

Outside Diameter	Length: End of Pipe to Hand-tight Plane	Effective Length	Total Length: End of Pipe to Vanish Point	Pitch Diameter at Handtight Plane	End of Pipe to Center of Coupling, Made Up	Diameter of Recess	Length: Face of Coupling to Handtight Plane	Width of Bearing Face
	L_1	L_3	L_4	E_1	J	Q	M	R
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
2 3/8	1.216	1.889	2.125	2.56167	.5625	2.781	.534	5/32
2 7/8	1.716	2.389	2.625	3.12467	.5625	3.344	.534	3/16
3 1/2	1.716	2.389	2.625	3.72967	.5625	3.949	.534	1/4
4	2.466	3.139	3.375	4.40567	.5625	4.625	.534	1/4
4 1/2	2.466	3.139	3.375	4.90567	.5625	5.125	.534	1/4
5 9/16	2.716	3.389	3.625	5.96867	.5625	6.188	.534	1/4
6 5/8	2.966	3.639	3.875	7.03067	.5625	7.250	.534	5/16

*Tentative as of November, 1940. Depth of Recess "q" is 1/8" on all sizes. Handtight standoff "A" is 3 threads on all sizes. Included taper is 0.0625" per inch on all sizes.



Pittsburgh Special

Acme-Thread Oil Well Tubing Earns its place in the well

After numerous round trips doing many extra-service tubing jobs, Pittsburgh Special Acme-Thread Oil Well Tubing is still ready to go into the well and give long, leak-proof oil-flow and pumping service under any deep-well and high-pressure conditions. Note the features of its construction which, combined with "Pittsburgh" quality and craftsmanship, make this such a superior tubing.

EXTRA FEATURES

Extra shoulder seal* shuts out corrosive fluids—eliminates V-notch weakness in last engaged thread. Sturdy six-pitch acme-type threads make and break repeatedly without galling.

Added shoulder contact provides extra strength and supports against fatigue.

Double-seal prevents gas or oil leakage at high pressures even after numerous round trips.

*The same Double-Grip joint as used in Pittsburgh Special Drill Pipe, Patent No. 1942518.

EXTRA SERVICES PERFORMED

1. Acidizing. . . .

2. Squeeze jobs. . . .

3. Drilling-in. . . . .

4. Drilling-out Casing. . . .

5. Fishing and Washing. . . .

6. Perforating and Cutting. . . .

7. Reconditioning and other jobs requiring several trips in and out of well. . . .

8. Superior service as oil well tubing.

PITTSBURGH SPECIAL ACME-THREAD OIL WELL TUBING

External Upset

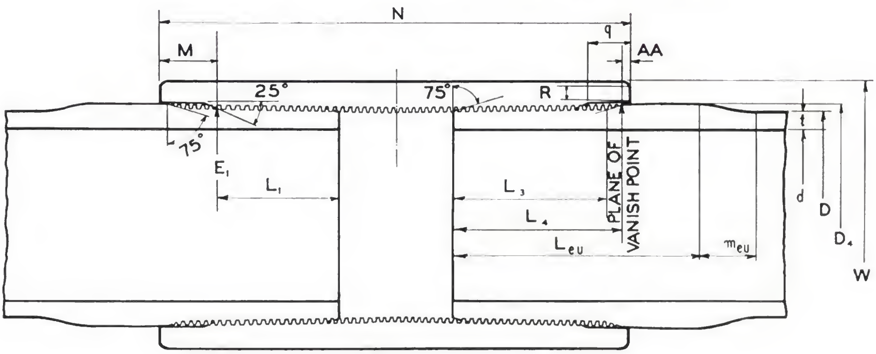
Nominal Size	Weight Per Foot		† GRADE J-55					† GRADE N-80					Internal Test Pressures Per Sq. In.		Diameters		Drift Diameter	Wall Thickness	D/t Ratio	Upset		Coupling	
			Collapsing Pressures		Minimum Strength of Joint			Collapsing Pressures		Minimum Strength of Joint													
	Nominal Threads and Couplings	Plain Ends	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 1	Internal Pressure at Min. Yield Strength P.S.I.	Minimum P.S.I.	Equiv. Length S.F. 1⅛	1000 Pounds	Equiv. Length S.F. 1	Internal Pressure at Min. Yield Strength P.S.I.	J-55	N-80	Outside	Inside				Diameter	Length	Outside Diameter	Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.
1¼	*2.40*	2.272	7530	13390	53.4	22280	8120	9850	17510	60.2	25070	11800	2800	2800	1.660	1.380	1.286	.140	11.86	1.867	2	2.200	4.250
1½	*2.90*	2.717	6870	12210	64.	22050	7350	8980	15960	72.	24810	10680	2800	2800	1.900	1.610	1.516	.145	13.10	2.152	2¼	2.500	4.375
2	*4.70*	4.433	7180	12760	104.	22200	7700	9380	16680	117.	24970	11200	2800	2800	2.375	1.995	1.901	.190	12.50	2.656	3½	3.063	5.500
2½	*6.50*	6.160	6800	12090	145.	22300	7260	8900	15820	163.	25090	10570	2800	2800	2.875	2.441	2.347	.217	13.25	3.156	3¾	3.668	6.000
3	*9.30*	8.805	6560	11660	207.	22280	6980	8580	15250	233.	25070	10160	2800	2800	3.500	2.992	2.867	.254	13.78	3.813	4	4.500	6.625
3½	*11.00*	10.459	5750	10220	246.	22380	6300	7520	13370	277.	25170	9170	2800	2800	4.000	3.476	3.351	.262	15.27	4.313	4	5.000	6.875
4	*12.75*	12.240	5110	9080	288.	22590	5790	6680	11880	324.	25410	8440	2800	2800	4.500	3.958	3.833	.271	16.61	4.813	4½	5.563	7.125

†We do not recommend any factors of safety nor guarantee setting depths. Such data given here as a matter of information only. Setting depth properties for collapse are based on new minimum values (75% of old averages); S.F. 1⅛ here corresponds to S.F. 1½ on old average collapse pressures and is based on setting depth in salt water at pressure of .5 lbs. per foot depth. Setting depth properties for tension load are based on minimum yield strength of body of pipe, S.F. 1; operators may figure own safety factors from this.

PITTSBURGH SPECIAL ACME-THREAD OIL WELL TUBING

Thread Dimensions

EXTERNAL UPSET—DOUBLE SEAL JOINT



Nominal Size	Length: End of Pipe to Handtight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Depth of Recess q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R	Face of Coupling to Vanish Point, Handtight AA
Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1¼	.657	1.109	1.375	1.721	.750	.822	⅛	.104
1½	.719	1.171	1.437	2.006	.750	.822	⅛	.104
2	1.219	1.671	1.937	2.510	.750	.822	5/32	.104
2½	1.407	1.859	2.125	3.010	.750	.822	7/32	.104
3	1.657	2.109	2.375	3.667	.750	.822	¼	.104
3½	1.782	2.234	2.500	4.167	.750	.822	¼	.104
4	1.907	2.359	2.625	4.667	.750	.822	¼	.104

PITTSBURGH SEAMLESS A P I STANDARD OIL WELL TUBING

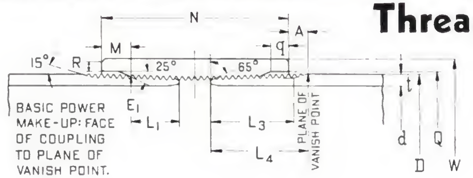
Nominal Size	Weight Per Foot: Nominal Threads and Couplings	Weight Per Foot: Plain Ends	†GRADE H-40: Collapsing Pressures: Minimum P.S.I.	†GRADE H-40: Collapsing Pressures: Equiv. Length S.F. $1\frac{1}{8}$	†GRADE H-40: Minimum Strength of Joint: 1000 Pounds	†GRADE H-40: Minimum Strength of Joint: Equiv. Length S.F. 1	†GRADE H-40: Internal Pressure at Min. Yield Strength P.S.I.	†GRADE J-55: Collapsing Pressures: Minimum P.S.I.	†GRADE J-55: Collapsing Pressures: Equiv. Length S.F. $1\frac{1}{8}$	†GRADE J-55: Minimum Strength of Joint: 1000 Pounds	†GRADE J-55: Minimum Strength of Joint: Equiv. Length S.F. 1	†GRADE J-55: Internal Pressure at Min. Yield Strength P.S.I.	†GRADE N-80: Collapsing Pressures: Minimum P.S.I.	†GRADE N-80: Collapsing Pressures: Equiv. Length S.F. $1\frac{1}{8}$	†GRADE N-80: Minimum Strength of Joint: 1000 Pounds	†GRADE N-80: Minimum Strength of Joint: Equiv. Length S.F. 1	†GRADE N-80: Internal Pressure at Min. Yield Strength P.S.I.	Internal Test Pressures Per Sq. In.: H-40	Internal Test Pressures Per Sq. In.: J-55	Internal Test Pressures Per Sq. In.: N-80	Diameters: Outside	Diameters: Inside	Drift Diameter	Wall Thickness	D/t Ratio	Upset: Diameter	Upset: Length	Coupling: Outside Diameter	Coupling: Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Lbs.	Lbs.	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.
A P I OIL WELL TUBING (NON UPSET)																													
1½	2.75	2.717	..	....	....	....	....	6870	12210	26.3	9550	7350	8980	15960	38.2	13880	10680	....	2800	2800	1.900	1.610	1.516	.145	13.10	....	....	2.200	3¾
2	4.60	4.433	5520	9810	36.	7820	5600	7180	12760	49.4	10750	7700	9380	16680	72.	15630	11200	2800	2800	2800	2.375	1.995	1.901	.190	12.50	....	....	2.875	4¼
2½	6.40	6.160	5240	9320	52.8	8250	5280	6800	12090	72.6	11340	7260	8900	15820	106.	16490	10570	2800	2800	2800	2.875	2.441	2.347	.217	13.25	....	....	3.500	5⅛
3	9.20	8.805	5050	8980	79.5	8650	5080	6560	11660	109.	11890	6980	8580	15250	159.	17290	10160	2800	2800	2800	3.500	2.992	2.867	.254	13.78	....	....	4.250	5⅝
*3	10.20	9.910	....	....	....	....	....	7390	13140	127.	12480	7940	9660	17170	185.	18150	11560	....	2800	2800	3.500	2.922	2.797	.289	12.11	....	....	4.250	5⅝
3½	9.50	9.109	....	....	....	....	....	4650	8270	99.	10420	5440	6080	10810	144.	15160	7910	....	2800	2800	4.000	3.548	3.423	.226	17.70	....	....	4.750	5¾
4	12.60	12.240	....	....	....	....	....	5110	9080	144.	11390	5790	6680	11880	209.	16570	8440	..	2800	2800	4.500	3.958	3.833	.271	16.61	....	...	5.200	6⅛
A P I OIL WELL TUBING (EXTERNAL UPSET)																													
1¼	2.40	2.272	....	....	....	....	....	7530	13390	36.8	15320	8120	9850	17510	53.5	22280	11800	....	2800	2800	1.660	1.380	1.286	.140	11.86	1 13/16	2	2.200	3¾
1½	2.90	2.717	....	....	....	....	....	6870	12210	44.	15160	7350	8980	15960	64.0	22060	10680	....	2800	2800	1.900	1.610	1.516	.145	13.10	2 3/32	2¼	2.500	3⅞
2	4.70	4.433	5520	9810	52.1	11100	5600	7180	12760	71.7	15260	7700	9380	16680	104.	22200	11200	2800	2800	2800	2.375	1.995	1.901	.190	12.50	2 19/32	3½	3.063	4⅞
2½	6.50	6.160	5240	9320	72.5	11150	5280	6800	12090	99.7	15330	7260	8900	15820	145.	22300	10570	2800	2800	2800	2.875	2.441	2.347	.217	13.25	3 3/32	3¾	3.668	5¼
3	9.30	8.805	5050	8980	104.	11140	5080	6560	11660	142.	15320	6980	8580	15250	207.	22280	10160	2800	2800	2800	3.500	2.992	2.867	.254	13.78	3¾	4	4.500	5¾
3½	11.00	10.459	....	....	....	....	....	5750	10220	169.	15380	6300	7520	13370	246.	22380	9170	....	2800	....	4.000	3.476	3.351	.262	15.27	4¼	4	5.000	6
4	12.75	12.240	....	....	....	....	....	5110	9080	198.	15530	5790	6680	11880	288.	22590	8440	...	2800	2800	4.500	3.958	3.833	.271	16.61	4¾	4¼	5.563	6¼

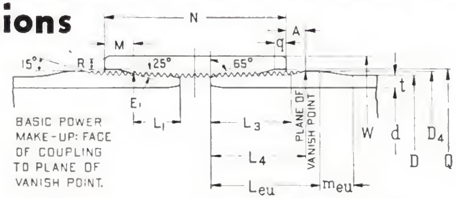
*Special order only.

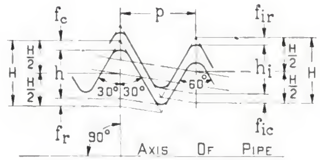
†We do not recommend any factors of safety nor guarantee setting depths. Such data given here as a matter of information only. Setting depth properties for collapse are based on new minimum values (75% of old averages); S.F. $1\frac{1}{8}$ here corresponds to S.F. $1\frac{1}{2}$ on old average collapse pressures and is based on setting depth in salt water at pressure of .5 lbs. per foot depth. Setting depth properties for tension load are based on minimum yield strength of joint for non-upset tubing and minimum yield strength of body of pipe for upset tubing, S.F. 1; operators may figure own safety factors from this.

PITTSBURGH SEAMLESS A P I STANDARD OIL WELL TUBING

Thread Dimensions

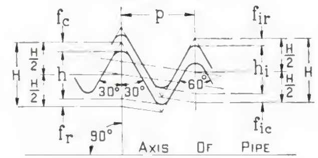






TAPER 1 IN 16 ON DIAMETER
(SHOWN EXAGGERATED IN DIAGRAM)

THREAD HEIGHT DIMENSIONS (INCHES)		
THREAD ELEMENT	10-THREADS PER INCH p = .100	8-THREADS PER INCH p = .125
H = .866 p	.08660	.10825
h = hi = .626 p - .007	.05560	.07125
fr = fir = .120 p + .002	.01400	.01700
fc = fic = .120 p + .005	.01700	.02000



TAPER 1 IN 16 ON DIAMETER
(SHOWN EXAGGERATED IN DIAGRAM)

NON-UPSET

Size Nominal	Nominal Weight	Threads Per Inch	Length: End of Pipe to Hand-tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Diameter of Recess Q	Depth of Recess q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R
Ins.	Lbs.	No.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1½	2.75	10	.729	1.206	1.375	1.83826	1.963	5/16	.446	1/16
2	4.60	10	.979	1.456	1.625	2.31326	2.438	5/16	.446	3/16
2½	6.40	10	1.417	1.894	2.063	2.81326	2.938	5/16	.446	3/16
3	9.20	10	1.667	2.144	2.313	3.43826	3.563	5/16	.446	3/16
*3	10.20	10	1.667	2.144	2.313	3.43826	3.563	5/16	.446	3/16
3½	9.50	8	1.591	2.140	2.375	3.91395	4.063	3/8	.534	3/16
4	12.60	8	1.779	2.328	2.563	4.41395	4.563	3/8	.534	3/16

*Special Order only. End of pipe to center of coupling, made up "J" is 0.500" on all sizes. Handtight standoff "A" is 2 threads on all sizes. Included taper is 0.0625" per inch on all sizes.

EXTERNAL UPSET

Size Nominal	Nominal Weight	Threads Per Inch	Length: End of Pipe to Hand-tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	Diameter of Recess Q	Depth of Recess q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R
Ins.	Lbs.	No.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1¼	2.40	10	.729	1.206	1.375	1.75079	1.875	5/16	.446	1/8
1½	2.90	10	.792	1.269	1.438	2.03206	2.156	5/16	.446	1/8
2	4.70	8	1.154	1.703	1.938	2.50775	2.656	3/8	.534	5/32
2½	6.50	8	1.341	1.890	2.125	3.00775	3.156	3/8	.534	7/32
3	9.30	8	1.591	2.140	2.375	3.66395	3.813	3/8	.534	1/4
3½	11.00	8	1.716	2.265	2.500	4.16395	4.313	3/8	.534	1/4
4	12.75	8	1.841	2.390	2.625	4.66395	4.813	3/8	.534	1/4

End of pipe to center of coupling, made up "J" is 0.500" on all sizes. Handtight standoff "A" is 2 threads on all sizes. Included taper is 0.0625" per inch on all sizes.

PITTSBURGH SEAMLESS OIL WELL TUBING
Hughes Plunger Lift Type

Nominal Size	Weight Per Foot: Nominal Threads and Couplings	Weight Per Foot: Plain Ends	†GRADE J-55: Collapsing Pressures: Minimum P.S.I.	†GRADE J-55: Collapsing Pressures: Equiv. Length S.F. 1⅛	†GRADE J-55: Minimum Strength of Joint: 1000 Pounds	†GRADE J-55: Minimum Strength of Joint: Equiv. Length S.F. 1	†GRADE J-55: Internal Pressure at Min. Yield Strength P.S.I.	†GRADE N-80: Collapsing Pressures: Minimum P.S.I.	†GRADE N-80: Collapsing Pressures: Equiv. Length S.F. 1⅛	†GRADE N-80: Minimum Strength of Joint: 1000 Pounds	†GRADE N-80: Minimum Strength of Joint: Equiv. Length S.F. 1	†GRADE N-80: Internal Pressure at Min. Yield Strength P.S.I.	Internal Test Pressures Per Sq. In. J-55 N-80	Diameters: Outside	Diameters: Inside	Wall Thickness	D/t Ratio	Upset: Diameter	Upset: Length	Coupling: Outside Diameter	Coupling: Length
Ins.	Lbs.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ft.		Ft.	Lbs.	Lbs.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.
PLUNGER LIFT TUBING (NOT UPSET)																					
2	*3.900*	3.795	† 6000	10170	39.1	10030	6500	† 7840	13930	56.9	14590	9460	2800	2.375	2.054	.1605	14.80	......	......	2.875	4¼
2½	*5.580*	5.382	5720	10160	60.0	10750	6270	7460	13260	87.2	15630	9130	2800	2.875	2.500	.1875	15.33	......	......	3.500	5⅛
3	*7.670*	7.379	5100	9060	86.3	11250	5780	6630	11790	126	16360	8400	2800	3.500	3.080	.2100	16.66	......	......	4.250	5⅝
4	*12.600*	12.240	5120	9110	143	11390	5790	6670	11850	209	16560	8440	2800	4.500	3.958	.2710	16.61	......	......	5.200	6⅛
PLUNGER LIFT TUBING (EXTERNAL UPSET)																					
2	*4.070*	3.795	6000	10170	61.4	15090	6500	7830	13930	89.3	21940	9460	2800	2.375	2.054	.1605	14.80	2.594	3.500	3.063	4⅞
2½	*5.730*	5.382	5720	10160	87.0	15190	6270	7460	13260	126	22100	9130	2800	2.875	2.500	.1875	15.33	3.094	3.750	3.668	5¼
3	*7.890*	7.379	5100	9060	119	15130	5780	6630	11790	174	22000	8400	2800	3.500	3.080	.2100	16.66	3.750	4.000	4.500	5¾
4	*12.750*	12.240	5120	9110	198	15530	5790	6670	11850	288	22590	8440	2800	4.500	3.958	.2710	16.61	4.750	4.250	5.563	6¼

†We do not recommend any factors of safety nor guarantee setting depths. Such data given here as a matter of information only. Setting depth properties for collapse are based on new minimum values (75% of old averages); S.F. 1⅛ here corresponds to S.F. 1½ on old average collapse pressures and is based on setting depth in salt water at pressure of .5 lbs. per foot depth. Setting depth properties for tension load are based on minimum yield strength of joint for non-upset tubing and minimum yield strength of body of pipe for upset tubing, S.F. 1; operators may figure own safety factors from this.

PITTSBURGH SEAMLESS A P I STANDARD THREADED LINE PIPE

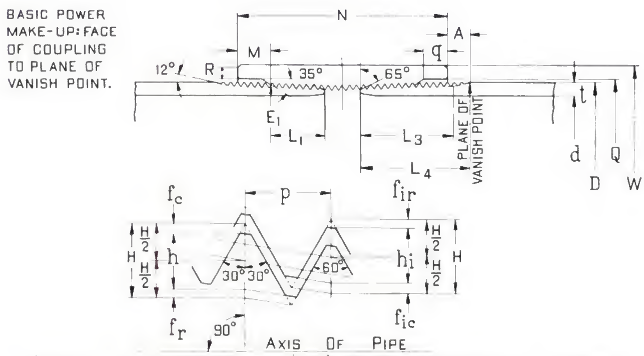
Nominal Size Inches	Weight per Foot: Nominal Threaded and Coupled*1 (Pounds)	Weight per Foot: Calculated Plain End*2 (Pounds)	Weight per Foot: Calculated Threaded and Coupled*2 (Pounds)	Wall Thickness Inches	Diameters: External O. D. Inches	Diameters: Internal I. D. Inches	Threads Per Inch	Mill Test Pressures: Grade A (P.S.I.)	Mill Test Pressures: Grade B (P.S.I.)	Mill Test Pressures: Grade C (P.S.I.)	Couplings: Outside Diameter Inches	Couplings: Length Inches	Couplings: Calculated Weight (Pounds)
1/8	.25	.24	.25	.068	.405	.269	27	700	700	700	.563	1 1/16	.04
1/4	.43	.42	.43	.088	.540	.364	18	700	700	700	.719	1 5/8	.09
3/8	.57	.57	.57	.091	.675	.493	18	700	700	700	.875	1 5/8	.13
1/2	.86	.85	.86	.109	.840	.622	14	700	700	700	1.063	2 1/8	.24
3/4	1.14	1.13	1.14	.113	1.050	.824	14	700	700	700	1.313	2 1/8	.34
1	1.70	1.68	1.69	.133	1.315	1.049	11 1/2	700	700	700	1.576	2 5/8	.54
1 1/4	2.30	2.27	2.30	.140	1.660	1.380	11 1/2	1000	1100	1300	2.054	2 3/4	1.03
1 1/2	2.75	2.72	2.74	.145	1.900	1.610	11 1/2	1000	1100	1300	2.200	2 3/4	.90
2	3.75	3.65	3.72	.154	2.375	2.067	11 1/2	1000	1100	1300	2.875	3 1/4	2.13
2 1/2	5.90	5.79	5.88	.203	2.875	2.469	8	1000	1100	1300	3.375	4 1/8	3.27
3	7.70	7.58	7.67	.216	3.500	3.068	8	1000	1100	1300	4.000	4 1/4	4.09
3 1/2	9.25	9.11	9.27	.226	4.000	3.548	8	1200	1300	1600	4.625	4 3/8	5.92
4	11.00	10.79	11.01	.237	4.500	4.026	8	1200	1300	1600	5.200	4 1/2	7.59
5	15.00	14.62	14.90	.258	5.563	5.047	8	1200	1300	1600	6.296	4 5/8	9.98
6	19.45	18.97	19.33	.280	6.625	6.065	8	1200	1300	1600	7.390	4 7/8	12.92
8	25.55	24.70	25.44	.277	8.625	8.071	8	1200	1300	1600	9.625	5 1/4	23.18
8	29.35	28.55	29.25	.322	8.625	7.981	8	1200	1300	1600	9.625	5 1/4	23.18
10	32.75	31.20	32.20	.279	10.750	10.192	8	1000	1200	1400	11.750	5 3/4	31.55
10	35.75	34.24	35.20	.307	10.750	10.136	8	1000	1200	1400	11.750	5 3/4	31.55
10	41.85	40.48	41.35	.365	10.750	10.020	8	1000	1200	1400	11.750	5 3/4	31.55
12	45.45	43.77	45.40	.330	12.750	12.090	8	1000	1200	1400	14.000	6 1/8	49.27
12	51.15	49.56	51.10	.375	12.750	12.000	8	1000	1200	1400	14.000	6 1/8	49.27

*1 "Nominal" Weights (Threads and Couplings) are included for convenience in ordering.

*2 "Calculated" Weights figured in accordance with tabular values of wall thickness, coupling dimensions, etc., the calculated weight of "Threaded and Coupled" being based on 20 foot lengths.

PITTSBURGH SEAMLESS API STANDARD THREADED LINE PIPE

Thread Dimensions



TAPER 1 IN 16 ON DIAMETER (SHOWN EXAGGERATED IN DIAGRAM)

THREAD HEIGHT DIMENSIONS (INCHES)					
THREAD ELEMENT	27-THREADS PER INCH $p = .0370$	18-THREADS PER INCH $p = .0556$	14-THREADS PER INCH $p = .0714$	11½-THREADS PER INCH $p = .0870$	8-THREADS PER INCH $p = .125$
$H = .866p$	.0321	.0481	.0619	.0753	.1082
$h = h_i = .760p$	.0281	.0422	.0543	.0661	.0950
$f_r = f_{ir} = .033p$	.0012	.0018	.0024	.0029	.0041
$f_c = f_{ic} = .073p$	.0027	.0041	.0052	.0063	.0091

Size Nominal	Nominal Weight	Length: End of Pipe to Handtight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Handtight Plane E_1	End of Pipe to Center of Couplings Made-Up J	Diameter of Recess Q	Depth of Recess q	Length: Face of Coupling to Handtight Plane M	Width of Bearing Face R	Handtight Stand-off A
Ins.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Thds.
1/8	.25	.180	.2639	.3924	.37476	.1389	.468	.0347	.1014	1/32	3
1/4	.43	.200	.4018	.5946	.48989	.2179	.603	.1471	.2278	1/32	3
3/8	.57	.240	.4078	.6006	.62701	.2119	.738	.1147	.1938	1/32	3
1/2	.86	.320	.5337	.7815	.77843	.2810	.903	.1582	.2473	1/16	3
3/4	1.14	.339	.5457	.7935	.98887	.2690	1.113	.1516	.2403	1/16	3
1	1.70	.400	.6828	.9845	1.23863	.3280	1.378	.2241	.3235	3/32	3
1 1/4	2.30	.420	.7068	1.0085	1.58338	.3665	1.723	.2279	.3275	3/32	3
1 1/2	2.75	.420	.7235	1.0252	1.82224	.3498	1.963	.2439	.3442	3/32	3
2	3.75	.668	.9884	1.2901	2.29627	.3349	2.469	.2379	.3611	1/8	3
2 1/2	5.90	.682	1.1375	1.5712	2.76216	.4913	2.969	.4915	.6392	3/16	2
3	7.70	.766	1.2000	1.6337	3.38850	.4913	3.594	.4710	.6177	3/16	2
3 1/2	9.25	.821	1.2500	1.6837	3.88881	.5038	4.094	.4662	.6127	3/16	2
4	11.00	.844	1.3000	1.7337	4.38713	.5163	4.594	.4920	.6397	1/4	2
5	15.00	.937	1.4063	1.8400	5.44929	.4725	5.657	.5047	.6530	1/4	2
6	19.45	.958	1.5125	1.9462	6.50597	.4913	6.719	.5861	.7382	1/4	2
8	All	1.063	1.7125	2.1462	8.50003	.4788	8.719	.6768	.8332	1/4	2
10	All	1.210	1.9250	2.3587	10.62094	.5163	10.844	.7394	.8987	3/8	2
12	All	1.360	2.1250	2.5587	12.61781	.5038	12.844	.7872	.9487	3/8	2

PITTSBURGH SEAMLESS A P I STANDARD PLAIN END LINE PIPE

Regular Weight—Light Weight—Extra Strong

Outside Diameter	Inside Diameter	Weight Per Foot	Wall Thickness	Internal Test Pressures P.S.I. Grade A	Grade B	Grade C
Ins.	Ins.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
REGULAR WEIGHT						
3½	3.124	6.63	.188	1900	2200	2500
3½	3.068	7.58	.216	2200	2500	2500
3½	3.000	8.68	.250	2500	2500	2500
3½	2.938	9.67	.281	2500	2500	2500
3½	2.900	10.25	.300	2500	2500	2500
4½	4.124	8.64	.188	1500	1800	2200
4½	4.062	10.00	.219	1700	2000	2500
4½	4.026	10.79	.237	1900	2200	2500
4½	4.000	11.35	.250	2000	2300	2500
4½	3.938	12.67	.281	2200	2500	2500
4½	3.876	13.98	.312	2500	2500	2500
4½	3.826	14.98	.337	2500	2500	2500
6⅝	6.249	12.89	.188	1000	1200	1500
6⅝	6.187	14.97	.219	1200	1400	1800
6⅝	6.125	17.02	.250	1400	1600	2000
6⅝	6.065	18.97	.280	1500	1800	2300
6⅝	6.001	21.07	.312	1700	2000	2500
6⅝	5.937	23.06	.344	1900	2200	2500
6⅝	5.875	25.03	.375	2000	2400	2500
6⅝	5.761	28.57	.432	2300	2500	2500
8⅝	8.249	16.90	.188	800	900	1200
8⅝	8.187	19.64	.219	900	1100	1400
8⅝	8.125	22.36	.250	1000	1200	1600
8⅝	8.071	24.70	.277	1200	1300	1700
8⅝	8.001	27.74	.312	1300	1500	2000
8⅝	7.981	28.55	.322	1300	1600	2000
8⅝	7.937	30.40	.344	1400	1700	2200
8⅝	7.875	33.04	.375	1600	1800	2300
8⅝	7.749	38.26	.438	1800	2100	2500
8⅝	7.625	43.39	.500	2100	2400	2500
10¾	10.312	24.60	.219	750	850	1100
10¾	10.250	28.04	.250	850	1000	1300

Outside Diameter	Inside Diameter	Weight Per Foot	Wall Thickness	Internal Test Pressures P.S.I. Grade A	Grade B	Grade C
Ins.	Ins.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
REGULAR WEIGHT—Cont'd						
10¾	10.192	31.20	.279	1000	1200	1400
10¾	10.136	34.24	.307	1000	1200	1500
10¾	10.062	38.20	.344	1100	1300	1700
10¾	10.020	40.48	.365	1200	1400	1800
10¾	9.874	48.19	.438	1500	1700	2200
10¾	9.750	54.74	.500	1700	2000	2500
12¾	12.250	33.38	.250	700	800	1100
12¾	12.188	37.45	.281	800	950	1200
12¾	12.126	41.51	.312	900	1000	1300
12¾	12.090	43.77	.330	1000	1200	1400
12¾	12.062	45.55	.344	1000	1200	1500
12¾	12.000	49.56	.375	1100	1200	1600
12¾	11.874	57.53	.438	1200	1400	1900
12¾	11.750	65.42	.500	1400	1600	2100
***LIGHT WEIGHT**						
3½	3.250	4.51	.125	1300	1500	1900
3½	3.188	5.58	.156	1600	1900	2400
4	3.750	5.17	.125	1100	1300	1700
4	3.688	6.41	.156	1400	1600	2100
4	3.624	7.63	.188	1700	2000	2500
4	3.548	9.11	.226	2000	2400	2500
4	3.500	10.01	.250	2200	2500	2500
4	3.438	11.17	.281	2500	2500	2500
4	3.364	12.51	.318	2500	2500	2500
4½	4.250	5.84	.125	1000	1200	1500
4½	4.188	7.25	.156	1200	1500	1900
5 9/16	5.251	9.02	.156	1000	1200	1500
5 9/16	5.187	10.76	.188	1200	1400	1800
5 9/16	5.125	12.49	.219	1400	1700	2100
5 9/16	5.047	14.62	.258	1700	1900	2500
5 9/16	5.001	15.87	.281	1800	2100	2500

Outside Diameter	Inside Diameter	Weight Per Foot	Wall Thickness	Internal Test Pressures P.S.I. Grade A	Grade B	Grade C
Ins.	Ins.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
***LIGHT WEIGHT—Cont'd**						
5 9/16	4.939	17.52	.312	2000	2400	2500
5 9/16	4.875	19.16	.344	2200	2500	2500
5 9/16	4.813	20.78	.375	2400	2500	2500
10¾	10.374	21.15	.188	650	750	950
12¾	12.312	29.28	.219	600	700	950

EXTRA STRONG

Size Nominal	Outside Diameter	Inside Diameter	Weight Per Foot	Wall Thickness	Internal Test Pressures P.S.I. Grade A	Grade B	Grade C
Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.
⅛	.405	.215	.31	.095	850	850	850
¼	.540	.302	.54	.119	850	850	850
⅜	.675	.423	.74	.126	850	850	850
½	.840	.546	1.09	.147	850	850	850
¾	1.050	.742	1.47	.154	850	850	850
1	1.315	.957	2.17	.179	850	850	850
1¼	1.660	1.278	3.00	.191	1800	1900	2300
1½	1.900	1.500	3.63	.200	1800	1900	2300
2	2.375	1.939	5.02	.218	1800	1900	2300
2½	2.875	2.323	7.66	.276	1800	1900	2300
3	3.500	2.900	10.25	.300	2500	2500	2500
3½	4.000	3.364	12.51	.318	2500	2500	2500
4	4.500	3.826	14.98	.337	2500	2500	2500
5	5.563	4.813	20.78	.375	2400	2500	2500
6	6.625	5.761	28.57	.432	2300	2500	2500
8	8.625	7.625	43.39	.500	2100	2400	2500
10	10.750	9.750	54.74	.500	1700	2000	2500
12	12.750	11.750	65.42	.500	1400	1600	2100

*Light Weight sizes are not regularly available for immediate shipment.

PITTSBURGH SEAMLESS A P I STANDARD LINE PIPE

Plain End

Nominal Size Inches	Weight per Foot	Diameters		Wall Thickness	Mill Test Pressures		
		External O.D. Inches	Internal I.D. Inches		Grade A	Grade B	Grade C
1/8	*.24*	.405	.269	.068	700	700	700
1/4	*.42*	.540	.364	.088	700	700	700
3/8	*.57*	.675	.493	.091	700	700	700
1/2	*.85*	.840	.622	.109	700	700	700
3/4	*1.13*	1.050	.824	.113	700	700	700
1	*1.68*	1.315	1.049	.133	700	700	700
1 1/4	*2.27*	1.660	1.380	.140	1200	1300	1600
1 1/2	*2.72*	1.900	1.610	.145	1200	1300	1600
2	*3.65*	2.375	2.067	.154	1200	1300	1600
2 1/2	*5.79*	2.875	2.469	.203	1200	1300	1600

PITTSBURGH SEAMLESS STANDARD PIPE

All weights and dimensions are nominal. Details of joint and threading data on page P49.

Nominal Size Inches	†Weight per Foot		Wall Thickness Inches	Diameters		Threads per Inch	Mill Test Pressure Grade A (P.S.I.)	Mill Test Pressure Grade B (P.S.I.)	Couplings		
	Threads and Couplings Pounds	Plain End Pounds		External O. D. Inches	Internal I. D. Inches				O. D. Inches	Length Inches	Weight (Pounds)
1/8	*.24*	.24	.068	.405	.269	27	700	700	.563	13/16	.03
1/4	*.42*	.42	.088	.540	.364	18	700	700	.719	1 3/16	.07
3/8	*.57*	.57	.091	.675	.493	18	700	700	.875	1 3/16	.09
1/2	*.85*	.85	.109	.840	.622	14	700	700	1.063	1 9/16	.17
3/4	*1.13*	1.13	.113	1.050	.824	14	700	700	1.313	1 5/8	.26
1	*1.68*	1.68	.133	1.315	1.049	11 1/2	700	700	1.576	2	.40
1 1/4	*2.28*	2.27	.140	1.660	1.380	11 1/2	1000	1100	1.900	2 1/16	.48
1 1/2	*2.73*	2.72	.145	1.900	1.610	11 1/2	1000	1100	2.200	2 1/16	.67
2	*3.68*	3.65	.154	2.375	2.067	11 1/2	1000	1100	2.750	2 1/8	1.05
2 1/2	*5.82*	5.79	.203	2.875	2.469	8	1000	1100	3.250	3 1/8	2.09
3	*7.62*	7.58	.216	3.500	3.068	8	1000	1100	4.000	3 1/4	3.35
3 1/2	*9.20*	9.11	.226	4.000	3.548	8	1200	1300	4.625	3 3/8	4.82
4	*10.89*	10.79	.237	4.500	4.026	8	1200	1300	5.000	3 1/2	4.61
5	*14.81*	14.62	.258	5.563	5.047	8	1200	1300	6.296	3 3/4	8.52
6	*19.18*	18.97	.280	6.625	6.065	8	1200	1300	7.390	4	11.27

† Weights as per A I S I Section 18.

Furnished with threads and couplings in random lengths unless otherwise specified. Weight per foot of pipe with threads and couplings is based on a length of 20 feet, including one coupling. Weight must be specified if a size is made in more than one weight. Permissible weight variation is 5% over or under. Taper of threads is 3/4″ per foot on diameter for all sizes.

PITTSBURGH SEAMLESS EXTRA STRONG PIPE

All weights and dimensions are nominal. Details of joint and threading data on page P50.

Nominal Size Inches	†Weight per Foot Plain End Pounds	Wall Thickness Inches	Diameters		Mill Test Pressure Grade A (P.S.I.)	Mill Test Pressure Grade B (P.S.I.)	Couplings	
			External Inches	Internal Inches			O. D. Inches	Length Inches
1/8	*.31*	.095	.405	.215	850	850	.563	1 1/16
1/4	*.54*	.119	.540	.302	850	850	.719	1 5/8
3/8	*.74*	.126	.675	.423	850	850	.875	1 5/8
1/2	*1.09*	.147	.840	.546	850	850	1.063	2 1/8
3/4	*1.47*	.154	1.050	.742	850	850	1.313	2 1/8
1	*2.17*	.179	1.315	.957	850	850	1.576	2 5/8
1 1/4	*3.00*	.191	1.660	1.278	1500	1600	2.054	2 3/4
1 1/2	*3.63*	.200	1.900	1.500	1500	1600	2.200	2 3/4
2	*5.04*	.219	2.375	1.937	1500	1600	2.875	3 1/4
2 1/2	*7.66*	.276	2.875	2.323	1500	1600	3.375	4 1/8
3	*10.25*	.300	3.500	2.900	1500	1600	4.000	4 1/4
3 1/2	*12.51*	.318	4.000	3.364	1700	1800	4.625	4 3/8
4	*14.98*	.337	4.500	3.826	1700	1800	5.200	4 1/2
5	*20.78*	.375	5.563	4.813	1700	1800	6.296	4 5/8
6	*28.57*	.432	6.625	5.761	1700	1800	7.390	4 7/8
8	*43.39*	.500	8.625	7.625	1700	2400	9.625	5 1/4
10	*54.74*	.500	10.750	9.750	1600	1900	11.750	5 3/4
12	*65.42*	.500	12.750	11.750	1600	1900	14.000	6 1/8

† Weights as per A I S I Section 18.

Furnished with plain ends and in random lengths unless otherwise specified. Permissible weight variation: 5% over or under.

PITTSBURGH SEAMLESS DOUBLE EXTRA STRONG PIPE

All weights and dimensions are nominal. Details of joint and threading data on page P50.

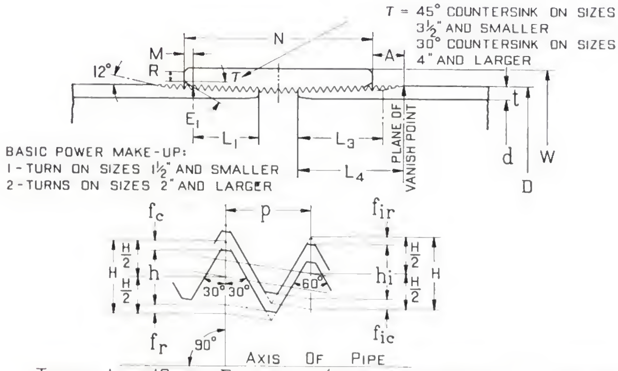
Nominal Size Inches	†Weight per Foot Plain End Pounds	Wall Thickness Inches	Diameters		Mill Test Pressure Grade A (P.S.I.)	Mill Test Pressure Grade B (P.S.I.)	Couplings	
			External Inches	Internal Inches			O. D. Inches	Length Inches
1/2	*1.71*	.294	.840	.252	1000	1000	1.063	2 1/8
3/4	*2.44*	.308	1.050	.434	1000	1000	1.313	2 1/8
1	*3.66*	.358	1.315	.599	1000	1000	1.576	2 5/8
1 1/4	*5.21*	.382	1.660	.896	1800	1900	2.054	2 3/4
1 1/2	*6.41*	.400	1.900	1.100	1800	1900	2.200	2 3/4
2	*9.03*	.436	2.375	1.503	1800	1900	2.875	3 1/4
2 1/2	*13.70*	.552	2.875	1.771	1800	1900	3.375	4 1/8
3	*18.58*	.600	3.500	2.300	1800	1900	4.000	4 1/4
4	*27.54*	.674	4.500	3.152	2000	2100	5.200	4 1/2
5	*38.55*	.750	5.563	4.063	2000	2100	6.296	4 5/8
6	*53.16*	.864	6.625	4.897	2000	2100	7.390	4 7/8
8	*72.42*	.875	8.625	6.875	2800	2800	9.625	5 1/4

† Weights as per A I S I Section 18.

Furnished with plain ends and in random lengths unless otherwise specified. Permissible weight variation: 10% over or under.

PITTSBURGH SEAMLESS STANDARD PIPE

Thread Dimensions



TAPER 1 IN 16 ON DIAMETER (SHOWN EXAGGERATED IN DIAGRAM)

THREAD HEIGHT DIMENSIONS (INCHES)					
THREAD ELEMENT	27-THREADS PER INCH p = .0370	18-THREADS PER INCH p = .0556	14-THREADS PER INCH p = .0714	11½-THREADS PER INCH p = .0870	8-THREADS PER INCH p = .125
$H = .866p$	.0321	.0481	.0619	.0753	.1082
$h = h_i = .760p$	.0281	.0422	.0543	.0661	.0950
$f_r = f_{ir} = .033p$	.0012	.0018	.0024	.0029	.0041
$f_c = f_{ic} = .073p$	.0027	.0041	.0052	.0063	.0091

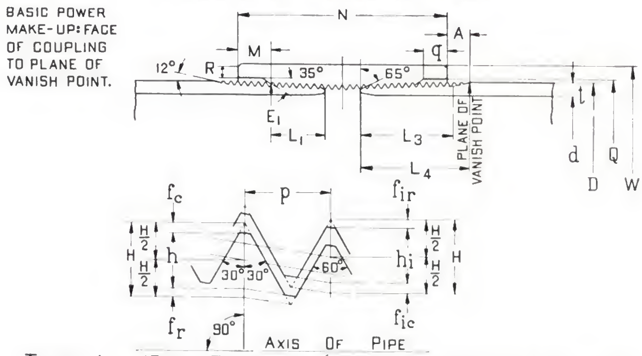
Nominal Size	Outside Diameter	Length from End of Pipe to Hand Tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Hand Tight Plane E_1	Length from Face of Coupling to Hand Tight Plane M	Width of Bearing Face R	Hand Tight Stand-off A
Ins.	Lbs.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Thrds.
1/8	.405	.180	.2638	.3924	.37476	.0556	Approximately 1/3 Thickness of Coupling	4.23
1/4	.540	.200	.4018	.5946	.48989	.0883		5.60
3/8	.675	.240	.4078	.6006	.62701	.0883		4.99
1/2	.840	.320	.5337	.7815	.77843	.1071		4.96
3/4	1.050	.339	.5457	.7935	.98887	.1071		4.86
1	1.315	.400	.6828	.9845	1.23863	.1304		5.22
1¼	1.660	.420	.7068	1.0085	1.58338	.1304		5.27
1½	1.900	.420	.7235	1.0252	1.82234	.1304		5.46
2	2.375	.436	.7565	1.0582	2.29627	.1304		5.66
2½	2.875	.682	1.1375	1.5712	2.76216	.1875		5.61
3	3.500	.766	1.2000	1.6337	3.38850	.1875		5.44
3½	4.000	.821	1.2500	1.6837	3.88881	.1875		5.40
4	4.500	.844	1.3000	1.7337	4.38713	.2500		5.12
5	5.563	.937	1.4063	1.8400	5.44929	.2500		5.22
6	6.625	.958	1.5125	1.9462	6.50597	.2500		5.91

Note—Couplings 2″ size and smaller to be straight tapped.

Taper of threads is ¾ in. per foot on diameter for all sizes.

PITTSBURGH SEAMLESS EXTRA STRONG AND DOUBLE EXTRA STRONG PIPE

Thread Dimensions



TAPER 1 IN 16 ON DIAMETER (SHOWN EXAGGERATED IN DIAGRAM)

THREAD HEIGHT DIMENSIONS (INCHES)					
THREAD ELEMENT	27-THREADS PER INCH p = .0370	18-THREADS PER INCH p = .0556	14-THREADS PER INCH p = .0714	$11\frac{1}{2}$-THREADS PER INCH p = .0870	8-THREADS PER INCH p = .125
$H = .866p$	.0321	.0481	.0619	.0753	.1082
$h = h_i = .760p$	.0281	.0422	.0543	.0661	.0950
$f_r = f_{ir} = .033p$	.0012	.0018	.0024	.0029	.0041
$f_c = f_{ic} = .073p$	.0027	.0041	.0052	.0063	.0091

Nominal Size	Outside Diameter	Threads per Inch	Length from End of Pipe to Hand Tight Plane L_1	Effective Length L_3	Total Length: End of Pipe to Vanish Point L_4	Pitch Diameter at Hand Tight Plane E_1	Diameter of Recess Q	Depth of Recess q	Length from Face of Coupling to Hand Tight Plane M	Width of Bearing Face R	Hand Tight Stand-off A
Ins.	Ins.	No.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Thrds.
1/8	.405	27	.180	.2638	.3924	.37476	.468	.0347	.1014	1/32	3
1/4	.540	18	.200	.4018	.5946	.48989	.603	.1471	.2278	1/32	3
3/8	.675	18	.240	.4078	.6006	.62701	.738	.1147	.1938	1/32	3
1/2	.840	14	.320	.5337	.7815	.77843	.903	.1582	.2473	1/16	3
3/4	1.050	14	.339	.5457	.7935	.98887	1.113	.1516	.2403	1/16	3
1	1.315	11½	.400	.6828	.9845	1.23863	1.378	.2241	.3235	3/32	3
1¼	1.660	11½	.420	.7068	1.0085	1.58338	1.723	.2279	.3275	3/32	3
1½	1.900	11½	.420	.7235	1.0252	1.82234	1.963	.2439	.3442	3/32	3
2*	2.375	11½	.436	.7565	1.0582	2.29627	2.469	.2379	.3611	1/8	3
2	2.375	11½	.668	.9884	1.2901	2.29627	2.469	.2379	.3611	1/8	3
2½	2.875	8	.682	1.1375	1.5712	2.76216	2.969	.4915	.6392	3/16	2
3	3.500	8	.766	1.2000	1.6337	3.38850	3.594	.4710	.6177	3/16	2
3½	4.000	8	.821	1.2500	1.6837	3.88881	4.094	.4662	.6127	3/16	2
4	4.500	8	.844	1.3000	1.7337	4.38713	4.594	.4920	.6397	1/4	2
5	5.563	8	.937	1.4063	1.8400	5.44929	5.657	.5047	.6530	1/4	2
6	6.625	8	.958	1.5125	1.9462	6.50597	6.719	.5861	.7382	1/4	2
8	8.625	8	1.063	1.7125	2.1462	8.50003	8.719	.6768	.8332	3/8	2
10	10.750	8	1.210	1.9250	2.3587	10.62094	10.844	.7394	.8987	3/8	2
12	12.750	8	1.360	2.1250	2.5587	12.61781	12.844	.7872	.9487	3/8	2

*American Standard Pipe Thread Length.

Taper of threads is ¾ in. per foot on diameter on all sizes.

FORMULAS AND CONSTANTS
Applying to Oil Country Tubular Material

AREA, Circular

Area in Sq. Ins. $= \frac{\pi D^2}{4} = .7854D^2$

Or $\pi R^2 = 3.1416R^2$

Where D = Diameter in inches
R = Radius in inches

AREA, Cylindrical

Area in Sq. Ins. = 3.1416 DL

Where D = Diameter in inches
L = Length of cylinder, in inches

AREA, of Metal in a Tubular Section

Area in Sq. Ins. = 3.1416 (D—t) t

Where D = Outside diameter in inches
t = Wall thickness in inches

AREA, Cross Sectional—Capacity

To convert internal tubular area to capacity

$B100 = .1237A = .0972\,D1^2$

Where B100 = Barrels per 100 feet.
A = Internal area of pipe in sq. ins.
D1 = Internal diameter in inches.

Also: $FB = \frac{808.5}{A} \quad \frac{1029.4}{D1^2}$

Where FB = Number of feet filled by one barrel.

BURSTING STRENGTH
Barlow's Formula

$$P = \frac{2St}{D}$$

Where P = Internal Pressure in lbs. per sq. in.
t = Wall thickness in inches
D = Outside diameter in inches
S = Ultimate tensile strength of metal in lbs. per sq. inch

COLLAPSING STRENGTH
Empirical Formulas

Lap Weld.............P = 86,730 t/D—1388
Seamless Grade "C"....P = 119,690 t/D—1915
Seamless Grade "D"....P = 151,350 t/D—2422

Where P = External Pressure in lbs. per sq. in.
D = Outside diameter in inches.
t = Wall thickness in inches.

Formulas are derived from experimental data as incorporated in latest A.P.I. collapse figures. They do not apply mathematically where t/D is less than .038, but are approximately correct down to t/D = .025.

STEEL
Constants applicable to Tubular Products

One cubic inch = 0.2833 pounds
One cubic foot = 489.542 pounds
Specific Gravity = 7.851

Coefficient of Expansion—(Approx.)

For commercial casing, drill pipe and tubing

Coef. = 6.9×10^6 per degree Fahrenheit (over range 0°F. to 400°F.)

The length of a pipe or string is:

Lt = Lo(1+.0000069t)

Where Lo = Length at temperature before heating (usually atmospheric).
Lt = Length at temperature after heating (as with steam).
t = Change in temperature (in degrees Fahrenheit).

The fibre stress at top of a wire, rod or tubular section, suspended freely, in pounds per sq. in. = 3.4 times length in feet.

WATER—Constants

Specific Gravity = 1.0000 at 4°C. (39.2°F.)

Density.

		39.2°F.	60°F.
One cubic inch	=	.03613	.03609 lbs.
One cubic foot	=	62.42500	62.36600 lbs.
One gallon (U. S.)	=	8.34500	8.33700 lbs.
One Barrel (42 gals.)	=	350.49000	350.16000 lbs.
One foot of height	=	0.43350*	0.43310*

**Lbs. per sq. in.*

WATER (Salt)

A.P.I. Collapse data are based on salt water having Specific Gravity of 1.154.

One cubic foot = 72,000 pounds at 60°F.
One Barrel (42 gals.) = 404.25 pounds at 60°F.
One foot of height = 0.5000 lbs. per sq. in. at 60°F.

A P I FIELD PRACTICE FOR RUNNING AND PULLING CASING

A. PREPARATION AND INSPECTION BEFORE RUNNING.

1. All casing, new, used, or reconditioned, should always be handled with protectors in place.
2. Run A P I drift plug through each joint.
3. Slip-type elevators are recommended for long strings.
4. If latch-type elevators are used, inspection should be made of bearing surface to insure against uneven wear or springing which might put a side lift on the coupling with danger of jumping it off.
5. Spider and elevator slips should be examined and watched to see that all lower together. If they lower unevenly, there is danger of dingeing the pipe or badly slip-cutting it.
6. Both spider and elevator slips must be clean and sharp and must fit properly. They should be extra long for exceptionally heavy strings.

LUBRICATION OF THREADED JOINTS.

*7. The proper lubrication of threads is highly important in obtaining proper tightness of the joint and in preventing galling. Extreme care must be exercised to prevent contamination of lubricant by any foreign matter, particularly sand and grit from derrick floor. The brush or utensil used in applying the lubricant must also be kept free of foreign matter. A proper lubricant should permit the joint to screw up smoothly, and recent studies indicate that it is also valuable as a sealing agent to prevent leaks. Zinc-dust lubricant has been universally used and has given good service in recent years. When zinc lubricant is used, it should never be thinned.

8. COUPLING END.
   - (a) Remove protectors from a number of joints on top row immediately before running and clean threads with soft pine paddle of hemp brush, and finish with steam or kerosene.
   - (b) Wire brush is unsatisfactory for cleaning.
   - (c) Inspect threads and if found to be damaged even slightly, couplings should be laid aside unless some satisfactory means are available for correcting the condition.
   - (d) When thoroughly dry, apply zinc lubricant* over entire thread surface.
   - (e) If using a steep ramp, clean protectors and reapply tightly.
9. FIELD END.
   - (a) Remove protectors from a number of joints on top row, clean and inspect threads and correct slightly damaged threads with three-cornered file. Lay aside any pipe that is badly damaged.
   - (b) When thoroughly dry apply zinc lubricant* over entire thread surface.
   - (c) Clean a number of protectors for use on joints which have been cleaned and inspected. Screw on re-cleaned protectors before further handling into derrick.
   - (d) On new pipe where the above rules are not properly observed, it is safer to run casing as received from the mill with the addition of zinc lubricant.
10. Lower or roll each piece of casing carefully to the walk without dropping. Use ropes if necessary.

11. Avoid hitting pipe against any part of derrick or equipment. Provide a hold-back rope at window.
12. Do not remove the protector from the cleaned pipe threads until casing is ready to stab.

B. STABBING, MAKING UP AND LOWERING OF CASING.

13. Apply zinc lubricant* on field threads just before stabbing.
14. Never thin zinc lubricant*.
15. Lower joints carefully when stabbing to avoid injuring threads.
16. Stab vertically. If pipe tilts to one side after stabbing, lift it up, file any damaged threads and re-grease* carefully.
17. After stabbing, it is desirable to use casing pole or hand tongs for the first part of the make-up, before use of any spinning line or table post. This will insure that threads are engaging properly and not cross-threading.
18. If spinning line is used, the joint should be rotated very slowly at first. Line should pull close to coupling.
19. After spinning there should be from two to six threads still exposed, depending upon the type of casing. (Heavier weights of casing show greater stand-off than lighter).
20. Tighten with tongs to proper degree of tightness, checked as follows:
    (a) Note action of the rig and jerk line for one joint as compared with another.
    (b) Note if there are any threads exposed. When screwed home, all, or nearly all, the threads should be covered and some sizes require a thread or two to be buried by the coupling recess. (See "R.R." Column, A P I Standards 5-A)
    (c) Place the bare hand on the coupling at frequent intervals. When the proper method is being used, the coupling will get uniformly warm. A hot spot on the coupling is an indication of galling.
21. It is not uncommon for the coupling to make up slightly on the mill end. This does not indicate that the couplings are too loose, but simply that the field end has reached the tightness with which the coupling was screwed on at the mill. However, excessive make-up might indicate improper make-up practice at the mill.
22. Although pipe is usually tallied on the rack, a string may be more accurately tallied in the derrick, under tension, just before lowering.
23. Casing should be lowered carefully. Dropping a string even a very short distance, will loosen the couplings at the bottom of the string. The string should be pulled and rerun, examining the bottom joints for telescoping.
24. Parted joints should never be reused, although they have little appearance of damage. Couplings near the parted joint are always loose, indicating that their pipe threads were also on the verge of jumping out, and should not be re-run without checking or re-threading. Mark those joints carefully to prevent further use without re-shopping.
25. In exceptionally long strings of casing, the cementing or landing joint should be of extra heavy-weight pipe to resist crushing by the slips.
26. Definite instructions should be expected on proper tension when finally landing pipe.

CONVERSION FACTORS
Applying to Oil Country Calculations

Acre = 43,560 Square feet
Acre = 4,047 Square meters
Acre = 160 Square rods
Acre = 5,645.4 Square varas (Texas)
Acre = 0.4047 Hectare
Acre foot = 7,758 Barrels

Atmosphere = 33.94 Feet of water
Atmosphere = 29.92 Inches of mercury
Atmosphere = 760.0 Millimeters of mercury
Atmosphere = 14.70 Pounds per square inch

Barrel = 5.6146 Cubic feet
Barrel = 42.0 Gallons
Barrel of water @ 60°F. = .1588 Metric ton
Barrel (36° A.P.I.) = 0.1342 Metric ton
Barrel per hour = 0.0936 Cubic foot per minute
Barrel per hour = 0.700 Gallon per minute
Barrel per hour = 2.695 Cubic inches per second
Barrel per day = .02917 Gallon per minute

British Thermal Unit = 0.2520 Kilogram calorie
British Thermal Unit = 0.2928 Watt hour
B.T.U. per minute = 0.02356 Horse power

Centimeter = 0.3937 Inch
Centimeter of mercury = 0.1934 Pound per sq. in.

Chain = 66.00 Feet
Chain = 4.00 Rods

Cubic centimeter = 0.06102 Cubic inch
Cubic foot = 0.1781 Barrel
Cubic foot = 7.4805 Gallons (U. S.)
Cubic foot = 0.02832 Cubic meter
Cubic foot per minute = 10.686 Barrels per hour
Cubic foot per minute = 28.800 Cubic inches per second
Cubic foot per minute = 7.481 Gallons per minute

Cubic inch = 16.387 Cubic centimeters
Cubic meter = 6.2897 Barrels
Cubic meter = 35.314 Cubic feet
Cubic meter = 1.308 Cubic yards

Cubic yard = 4.8089 Barrels
Cubic yard = 46,656 Cubic inches
Cubic yard = 0.7646 Cubic meter

Foot = 30.48 Centimeters
Foot = 0.3048 Meter
Foot = .3600 Vara (Texas)
Foot of water @ 60°F. = 0.4331 Pound per sq. in.
Foot per second = .68182 Mile per hour
Foot pound = 0.001286 British Thermal Unit
Foot pound per second = 0.001818 Horse power

Gallon (U. S.) = 0.02381 Barrel
Gallon (U. S.) = 0.1337 Cubic foot
Gallon (U. S.) = 231.000 Cubic inches
Gallon (U. S.) = 3.785 Litres
Gallon (U. S.) = 0.8327 Gallon (Imperial)

Gallon (Imperial) = 1.2009 Gallons (U. S.)
Gallon (Imperial) = 277.410 Cubic inches

Gallon per minute = 1.429 Barrels per hour
Gallons per minute = 0.1337 Cubic foot per minute
Gallons per minute = 34.286 Barrels per day

Grain (Avoirdupois) = 0.06480 Gram
Grain per gallon = 17.118 Parts per million
Grain per gallon = 142.86 Pounds per million gallons
Grain per gallon = 0.01714 Gram per liter

Gram = 15.432 Grains
Gram = 0.03527 Ounce
Gram per liter = 58.418 Grains per gallon

Hectare = 2.471 Acres
Hectare = 0.010 Square kilometer

Barrel above always means oil barrel = 42 gallons. *Gallon, unless otherwise noted, means U. S. Gallon.*

CONVERSION FACTORS—Continued
Applying to Oil Country Calculations

Horse-power = 42.44 B.T.U.'s per minute
Horse-power = 33,000 Foot-pounds per minute
Horse-power = 550 Foot-pounds per second
Horse-power = 1.014 Horse-power (metric)
Horse-power = 0.7457 Kilowatt
Horse-power hour = 2,547 British Thermal Units

Inch = 2.540 Centimeters
Inch of mercury = 1.134 Feet of water
Inch of mercury = 0.4912 Pounds per square inch
Inch of water @ 60°F. = 0.0361 Pound per sq. in.

Kilogram = 2.2046 Pounds
Kilogram Caloric = 3.968 British Thermal Units
Kilogram per square cm. = 14.223 Pounds per sq. in.

Kilometer = 3,281 Feet
Kilometer = 0.6214 Mile
Kilowatt = 1.341 Horse-power

Link (Surveyor's) = 7.92 Inches

Liter = 0.2642 Gallon
Liter = 1.0567 Quarts

Meter = 3.281 Feet
Meter = 39.37 Inches

Mile = 5,280 Feet
Mile = 1.609 Kilometers
Mile = 1,900.8 Varas (Texas)
Mile per hour = 1.4667 Feet per second

Ounce (Avoirdupois) = 437.5 Grains
Ounce (Avoirdupois) = 28.3495 Grams

Part per million = 0.05835 Grain per gallon
Part per million = 8.345 Pounds per million gals.

Pood (Russian) = 36.112 Pounds
Pound = 7,000 Grains
Pound = 0.4536 Kilogram

Pound per square inch = 2.309 Feet of water @ 60°F.
Pound per square inch = 2.0353 Inches of mercury
Pound per square inch = 51.697 Millimeters of mercury
Pounds per square inch = 0.0703 Kilogram per sq. cent.
Pound per million gals. = 0.00700 Grain per gallon
Pound per million gals. = 0.11982 Part per million

Quart (Liquid) = 0.946 Litre
Quintal (Mexican) = 101.467 Pounds

Rod = 16.5 Feet
Rod = 25.0 Links

Square centimeter = 0.1550 Square inch
Square foot = 0.0929 Square meter
Square foot = .1296 Square vara (Texas)
Square inch = 6.452 Square centimeters
Square kilometer = 0.3861 Square mile
Square meter = 10.76 Square feet
Square mile = 2.590 Square kilometers
Square vara (Texas) = 7.716 Square feet

Temp. Centigrade = 5/9 (Temp. Fahr.—32)
Temp. Fahrenheit = 9/5 Temp. Cent. + 32
Temp. Absolute C. = Temp. °C. + 273
Temp. Absolute F. = Temp. °F. + 460

Ton (Long) = 2,240 Pounds
Ton (Metric) = 2,205 Pounds
Ton (Short or Net) = 2,000 Pounds
Ton (Metric) = 1.102 Tons (Short or Net)
Ton (Metric) = 1,000 Kilograms
Ton (Metric) = 6.297 Barrels of water @ 60°F.
Ton (Metric) = 7.454 Barrels (36° A.P.I.)
Ton (Short or Net) = 0.907 Ton (Metric)

Vara (Texas) = 2.778 Feet
Vara (Texas) = 33.3333 Inches

Watt-hour = 3.415 British Thermal Units

Yard = 0.9144 Meter

Barrel above always means oil barrel = 42 gallons. *Gallon, unless otherwise noted, means U. S. Gallon.*

INDEX

API Casing Information.....P 13

API Field Practices for
  Casing................P 52-53

Annealing..................G 29

Billets, Piercing............G 20

Blooming...............G 16-17

Casing
  API, Standard.........P 16-20
  API, Discontinued....P 28 B-E
  Pittsburgh Special,
    Standard............P 21-26
  Pittsburgh Special,
    Discontinued.........P 28 A
  Collapse Pressure Charts P 14-15
  Setting Depths
    Comparisons.........P 11-12
  Specifications, and
    General Information...P 8-10

Cleaning...................P 7

Cold Drawing...........G 33-35

Conversion Factors.......P 54-55

Couplings..................P 3

Drill Pipe
  Pittsburgh Special......P 30-33
  API..................P 34-35
  Pittsburgh Special
    Thread Data...........P 36
  API Thread Data.........P 37
  Specifications, and
    General Information...P 8-10

Elongator Process...........G 23

Finishing..................P 2-7

Formulas and Constants.....P 51

General Information
  Concerning Pipe........P 8-10

Ingots, Pouring..........G 10-14

Ingots, Soaking and
  Rolling...............G 15-18

Inspection..................P 7

Length Ranges.............P 10

Line Pipe
  Plain End.............P 46-47
  Threaded.............P 44-45
  Specifications, and
    General Information...P 8-10

Normalizing...............G 28

Oil Well Tubing
  Pittsburgh Special......P 38-40
  API, Non-Upset and
    External Upset.......P 41-42
  Hughes Plunger Lift Type .P 43
  Specifications, and
    General Information...P 8-10

Oil Well Tubular Goods....P 1-55

Piercing Billets..........G 20-21

Pilger Process...........G 24-27

Pipe
  Double Extra Strong...P 48,50
  Drill.................P 30-37
  Extra Strong..........P 48,50
  Plain End...............P 47
  Standard..............P 47,49
  Specifications, and
    General Information...P 8-10

Pittsburgh Products..........G 3

Pressure, Collapsing......P 11-15

Reeling...................G 30

Rolling................G 22-28

Rules for Running Casing.P 52-53

Sinking...................G 31

Sizing....................G 31

Steel, Manufacture of......G 4-19

Setting Depths,
  Comparison of............P 12

Testing, Hydrostatic......P 6,28

Threading..................P 3

Tolerances.................P 9

Tool Joints, Proper
  Applications.............P 29

Tubes, Manufacture of...G 20-36

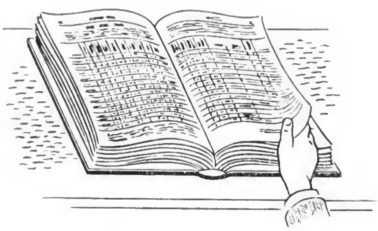
Pittsburgh Steel

CATALOG SECTION "D"

GENERAL DATA

In this General Data Section we present a convenient compilation of data frequently needed by anyone working with steel and steel products. Some of the information originates with our own technical staff, some comes by permission of the American Society of Metals, American Society for Testing Materials, and American Institute of Steel Construction. The source of some of the data is obscured in antiquity.

Technical Data specifically concerning a single group of our products will likely be found in that product group catalog section rather than in this section.



*GLOSSARY OF STEEL TERMS AND DEFINITIONS

(*Especially as Related to Ferrous Alloys*)

Foreword to Definitions—In the development of the knowledge of heat treating operations some confusion has arisen concerning the terms commonly used. For example, the term "annealing" is applied by some to any operation of heating and cooling which results in softening, while as applied by others, the term does not mean softening primarily but describes a treatment consisting in heating above the upper critical temperature in steel and cooling very slowly. Similar confusion has for many years attended the use of the terms "hardening" and "tempering."

In any attempt to define, accurately, commonly used terms, it is necessary to decide whether the terms are to relate to the operation performed, or to the properties thus determined; in general, the terms given will relate to the operations performed, though this is not always possible.

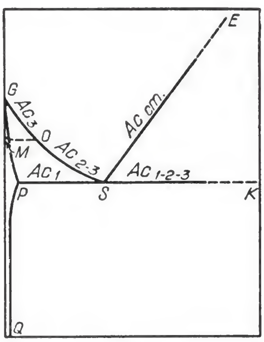


Fig. 1.

By critical temperatures, or by a critical temperature range, is meant those temperatures or that temperature range at which and in which iron-carbon alloys undergo transformation. Fig. 1 represents those schematically; all temperatures indicated are designated as transformation temperatures as determined on heating—this is the meaning of the *c* included in each term; it will be understood that Fig. 1 is not intended to give exact temperatures, for these vary with the rate of heating, are quite different on cooling, and vary with a number of factors. In Fig. 1 each line is appropriately designated; modern usage is veering toward the use of simple letters to designate the various lines, and these are also indicated in illustration.

Acid Bottom and Lining—The inner bottom and lining of a melting furnace composed of materials having an acid reaction in the melting process. The materials may be sand, siliceous rock, or silica brick.

Acid Brittleness—The brittleness induced in steel, especially wire or sheet, when pickled in dilute acid for the purpose of removing scale or upon electroplating. This brittleness is commonly attributed to the absorption of hydrogen.

Acid Steel—Steel melted in a furnace with an acid (siliceous) bottom and lining and under a slag which is dominantly siliceous.

Aging—The spontaneous change in properties of a metal which occurs at relatively low temperature after a final heat treatment or a final cold working operation. Aging is a process in which the trend is toward a restoration of real equilibrium, and away from an unstable condition induced by a prior operation.

**Source—American Society for Metals Handbook, 1939 Edition.*

Prepared by the Committee on Definitions: R. F. Mehl, Chairman; C. H. Mathewson, R. H. Aborn, and R. B. Schenck.

The fundamental reaction involved is generally one of precipitation, sometimes submicroscopic. The method employed to bring about aging consists of exposure to a favorable temperature subsequent to (a) a relatively rapid cooling from some elevated temperature (quench aging) or (b) a limited degree of cold work (strain aging).

Air Hardening Steel—An alloy steel which does not require quenching from a high temperature to harden, but which is hardened by simply cooling in air from above its critical temperature range.

Alloy—A mixture with metallic properties composed of two or more elements of which at least one is a metal.

Alloy Elements—Chemical elements comprising an alloy; in steels usually limited to the metallic elements added to steel to modify its properties.

Alpha Iron—See "Iron-Carbon Diagram," pages D-19-27.

Amorphous—Noncrystalline.

Annealing—A heating and cooling operation implying usually a relatively slow cooling.

Note—Annealing is a comparative term. The purpose of such a heat treatment may be:

(a) To remove stresses.
(b) To induce softness.
(c) To alter ductility, toughness, electrical, magnetic, or other physical properties.
(d) To refine the crystalline structure.
(e) To remove gases.
(f) To produce a definite microstructure.

In annealing, the temperature of the operation and the rate of cooling depend upon the material being heat treated and the purpose of the treatment.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

A. Full Annealing—Heating iron-base alloys above the critical temperature range, holding above that range for a proper period of time, followed by slow cooling to below that range.

Note—The annealing temperature is generally about 100°F. above the upper limit of the critical temperature range, and the time of holding is usually not less than 1 hr. for each inch of section of the heaviest objects being treated . . . . The objects being treated are ordinarily allowed to cool slowly in the furnace. They may, however, be removed from the furnace and cooled in some medium which will prolong the time of cooling as compared to unrestricted cooling in the air.

B. Process Annealing—Heating iron-base alloys to a temperature below or close to the lower limit of the critical temperature range followed by cooling as desired.

Note—This heat treatment is commonly applied in the sheet and wire industries, and the temperatures generally used are from 1020-1200°F.

C. Normalizing—Heating iron-base alloys to approximately 100°F. above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

D. Patenting—Heating iron-base alloys above the critical temperature range followed by cooling below that range in air, or in molten lead or a molten mixture of nitrates or nitrites maintained at a temperature usually between 800-1050°F., depending on the carbon content of the steel and the properties required of the finished product.

Note—This treatment is applied in the wire industry to medium or high carbon steel as a treatment to precede further wire drawing.

E. Spheroidizing—Any process of heating and cooling steel that produces a rounded or globular form of carbide.

Note—The spheroidizing methods generally used are:

(1) Prolonged heating at a temperature just below the lower critical temperature, usually followed by relatively slow cooling.

(2) In the case of small objects of high carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.

(3) Tool steel is generally spheroidized by heating to a temperature of 1380-1480°F. for carbon steels and higher for many alloy tool steels, holding at heat from 1-4 hours and cooling slowly in the furnace.

F. Tempering—(also termed drawing)—Reheating hardened steel to some temperature below the lower critical temperature, followed by any desired rate of cooling.

Note—Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.

G. Malleablizing—An annealing operation performed on white cast iron partially or wholly to transform the combined carbon to temper carbon, and in some cases wholly to remove the carbon from the iron by decarburization.

Note—Temper carbon is free graphitic carbon in the form of rounded nodules composed of an aggregate of minute crystals.

H. Graphitizing—Graphitizing is a type of annealing for gray cast iron whereby some or all of the combined carbon is transformed to free graphitic carbon.

Austenite—See "Iron-Carbon Diagram," pages D-19-27.

Banded Structure—A segregated structure of nearly parallel bands which run in the direction of working.

Bark—The decarburized skin or layer just beneath the scale found after heating steel in an oxidizing atmosphere.

Basic Bottom and Lining—The inner lining and bottom of a melting furnace composed of materials having a basic reaction in the melting process. The ma-

terials may be crushed burnt dolomite, magnesite, magnesite bricks, or basic slag.

Basic Steel—Steel melted in a furnace with a basic bottom and lining and under a slag which is dominantly basic.

Bessemer Process—A process for making steel by blowing air through molten pig iron contained in a suitable vessel. The process is one of rapid oxidation mainly of silicon and carbon.

Beta Iron—See "Iron-Carbon Diagram," pages D-19-27.

Billet—See bloom.

Billet Mill—See blooming mill.

Binary Alloy—An alloy containing two elements, apart from minor impurities.

Black Annealing—A process of box annealing of sheets prior to tinning whereby a black color is imparted to the surface of the product.

Blast Furnace—A shaft furnace supplied with air blast, usually hot, for producing pig iron by smelting iron ore. The furnace is continuous in operation, the raw materials (iron ore, coke, and limestone) are charged at the top, and the molten pig iron and slag are collected at the bottom and are tapped out at intervals.

Blister—A defect in metal produced by gas bubbles either on the surface or formed beneath the surface. Very fine blisters are called pinhead or pepper blisters.

Blister Bar—Wrought iron bars impregnated with carbon and formerly used in the manufacture of crucible steel. Also called blister steel.

Bloom—(slab, billet, sheet bar)—Semifinished products of rectangular cross section with rounded corners, hot rolled from ingots. The chief differences are in cross sectional area, in ratio of width to thickness, and in their intended use. American Iron and Steel Institute Manual classifies general usage as follows:

Type	Width, in.	Thickness, in.	Cross Section Area, sq. in.
Bloom	Width equals thickness		36 (min.)
Billet	1½ (min.)	1½ (min.)	2¼-36
Slab	10 + (min.)	1½ (min.)	16 (min.)
Sheet bar	8-16	¼-2†	2-32†

†Calculated from weight range 7-54 lb. per lineal foot.

Rerolling quality blooms, slabs, and billets are intended for hot rolling into shapes, plates, strip, bars, and wire rod.

Forging quality blooms, billets, and slabs are intended for conversion into forgings.

Sheet bar is converted by rolling into sheet, black plate, and tin plate.

Blooming Mill—A mill used to reduce ingots to blooms, billets, slabs, or sheet bars. Depending upon the product, the mill is called a blooming mill (cogging mill in England), a billet mill, or a slabbing mill.

Blowhole—A hole produced during the solidification of metal by evolved gas which, in failing to escape, is held in pockets.

Blue Annealing—A process of annealing sheets after rolling. The sheets, if fairly heavy, are allowed to cool slowly after the hot rolling; if of higher gage, as is usually the case, they are passed singly through an open furnace for heating to the proper annealing temperature. As the name indicates, the sheets have a bluish-black appearance.

Blue Brittleness—Brittleness occurring in steel when worked in the temperature range of 300-700°F., or when cold after being worked within this temperature range.

Box Annealing—Softening steel by heating, usually at a subcritical temperature, in a suitable closed metal box or pot to protect it from oxidation, employing a slow heating and cooling cycle; also called close annealing or pot annealing.

Bright Annealing—A process of annealing, usually with reducing gases, such that surface oxidation is reduced to a minimum, thereby yielding a relatively bright surface.

Burning—The heating of a metal to temperatures sufficiently close to the melting point to cause permanent injury. Such injury may be caused by the melting of the more fusible constituents, by the penetration of gases such as oxygen into the metal with consequent reactions, or perhaps by the segregation of elements already present in the metal.

Capped Steel—See rimmed steel.

Carbon Free—Metals and alloys which are practically free from carbon.

Carbon Steel—Steel which owes its properties chiefly to various percentages of carbon without substantial amounts of other alloying elements; also known as ordinary steel or straight carbon steel or plain carbon steel.

Carbonization—Coking or driving off the volatile matter from fuels such as coal and wood. (Carbonizing should not be confused with "carburizing.")

Carburizing (Cementation)—Adding carbon to the surface of iron-base alloys by heating the metal below its melting point in contact with carbonaceous solids, liquids, or gases.

Note—The term "carbonizing" is inadvisable and its use should be discouraged.

Case—The surface layer of an iron-base alloy which has been made substantially harder than the interior by the process of case hardening.

Case Hardening—A heat treatment or a combination of heat treatments in which the surface layer of an iron-base alloy is made substantially harder than the interior by altering its composition (carburizing or cyaniding, both of which are ordinarily followed by quenching, or by nitriding).

Cast Steel—Any object made by pouring molten steel into molds.

Casting Strains—Strains accompanied by internal stresses resulting from the cooling of a casting.

Cementite—See "Iron-Carbon Diagram," pages D-19-27.

Chill Cast Pig—Pig iron cast into metal molds or chills. If a machine is used, the product is known as machine cast pig.

Chipping—One method for removing seams and other surface defects with chisel or gouge, so that the defects will not be worked into the finished product. If the defects are removed by means of gas cutting, the term "deseaming" or "scarfing" is used. Chipping is often employed simply to remove metal apart from defects.

Cleavage Plane—It is frequently possible to fracture a crystal of a metal or other substance so that the surface of fracture is smooth and plane, and always parallel to some definite crystallographic plane. This crystallographic plane is known as a cleavage plane. A substance may cleave on more than one crystallographic plane.

Cogging—Rolling or forging ingots to reduce them to blooms.

Cogging Hammer—A forging hammer used to reduce ingots to blooms.

Cogging Mill—See blooming mill.

Cold Rolling—See cold working.

Cold Shut—A defect produced during casting of molten metal which may result from splashing, surging, interrupted pouring, or the meeting of two streams of metal coming from different directions. It may be due to the freezing of one surface before the other metal flows over it, or to the presence of interposing surface films or dirt on cold sluggish metal, or to any factor that will prevent a perfect union where two surfaces meet that should fuse and blend.

Cold Working—Plastic deformation of a metal at a temperature low enough to insure strain hardening.

Combined Carbon—All the carbon in iron or steel which is combined with iron or alloying elements to form carbide.

Core—The interior portion of an iron-base alloy which is substantially softer than the surface layer as the result of case hardening.

> Note—Also, that portion of a forging removed by trepanning; the inner part of a rolled section of rimmed steel as distinct from the rimmed portion or rim; a body of sand or other material placed in a mold to produce a cavity in a casting.

Cored Structure—A grain structure having composition gradients caused by the progressive freezing of the components in different proportions; the term "zonal structure" is in general preferable. In dendrites the cored or zonal structure is manifested by solvent-rich crystal axes and solute-rich interstices.

Critical Points—See "Iron-Carbon Diagram," pages D-19-27.

Critical Range—See critical points.

Critical Temperature—See critical points.

Crop—The end or ends of an ingot containing the pipe or other defects which are cut off and discarded; also termed "crop end" and "discard."

Cup Fracture—The form of fracture of a tension test specimen when the exterior portion is extended and the interior relatively depressed, so that it looks like a cup, as the name implies. When only a portion of the exterior is extended, the term "half cupped" or "quarter cupped" is used, as the case may be.

Cupping—A defect in wire which causes it to break with a cup fracture accompanied by very little reduction of area.

Cyaniding—Surface hardening by carbon and nitrogen absorption of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

Decalescence—The absorption of heat which occurs when steel is heated through the Ac_1 point.

Decarburization—The removal of carbon (usually refers to the surface of solid steel) by the (normally oxidizing) action of media which react with carbon.

Dendrite—A crystal formed by solidification, or in any other way, having many branches and a tree-like pattern; also termed "pine tree" and "fir tree" crystals.

Deseaming—See chipping.

Differential Heating—Heating conducted in such a way that various portions of an object attain different temperatures so that upon cooling different properties are produced.

Discard—See crop.

Dissolved Carbon—Carbon in solution in either the liquid or solid state.

Divorced Cementite—The cementite resulting from partial or complete spheroidization, frequently observed in some slowly cooled steels, particularly fine grained, aluminum killed steel.

Drawing Back—See tempering under annealing.

Elongation—The amount of permanent extension in the vicinity of the fracture in the tension test; usually expressed as a percentage of the original gage length, such as 25% in 2 in. It may also refer to the amount of extension at any stage in any process which continuously elongates a body, as in rolling.

Endurance Limit—A limiting stress, below which metal will withstand without fracture an indefinitely large number of cycles of stress. If the term is used without qualification, the cycles of stress are usually such as to produce complete reversal of flexural stress. Above this limit failure occurs by the generation and growth of cracks until fracture results in the remaining section.

Endurance Ratio—The ratio of the endurance limit for cycles of reversed flexural stress to the tensile strength.

Equilibrium—See "Iron-Carbon Diagram," pages D-19-27.

Eutectic Alloy—The composition in an alloy system at which two descending liquidus curves in a binary system or three descending liquidus surfaces in a ternary system intersect at a point. Such an alloy has thus a lower melting point than neighboring compositions. More than one eutectic composition may occur in a given alloy system.

Eutectoid Steel—A steel of the eutectoid composition. Composition S on the iron-carbon diagram. This composition in pure iron-carbon alloys is 0.80% C, but variations from this composition are found in commercial (impure) steels, and particularly in alloy steels in which the eutectoid composition is usually lower.

Exfoliation—The spalling or flaking off of the outer layer of an object.

Fatigue—The phenomenon of the progressive fracture of a metal by means of a crack which spreads under repeated cycles of stress.

Fatigue Limit—Usually used as synonymous with endurance limit.

Ferrite—See "Iron-Carbon Diagram," pages D-19-27.

Ferrite Ghost—A faint band of ferrite.

Ferroalloy—An alloy of iron with a sufficient amount of some element or elements, such as manganese, chromium, or vanadium, for use as a means of introducing these elements into steel by admixture to molten steel.

Fiber—A characteristic of wrought metal manifested by a fibrous or woody appearance of fractures and indicating directional properties. Fiber is caused chiefly by the extension in the direction of working of the constituents of the metal, both metallic and nonmetallic. This term also refers to the characteristic reorientation of the crystalline particles of the metal produced by a given deformation process.

Fiber Stress—Local unit stress at a point or line on a section over which stress is not uniform, such as the cross section of a beam under a bending load.

Fin—See flash.

Finished Steel—Steel which is ready for the market without further work or treatment. Blooms, billets, slabs, sheet bars, and wire rods are termed semi-finished.

Finishing Temperature—The temperature at which hot mechanical working of metal is completed.

Fir Tree Crystal—See dendrite.

Flakes (or "snow flakes")—Internal fissures in large steel forgings or massive rolled shapes. In a fractured surface or test piece they appear as sizable areas of silvery brightness and coarser grain size than their surroundings. Sometimes known as "chrome checks" and (when revealed by machining) "hairline cracks." Not to be confused with "woody fracture."

Flash—A thin fin of metal formed at the sides of a forging or weld where a small

portion of the metal is forced out between the edges of the forging or welding dies.

Forging Strains—Elastic strains resulting from forging or from cooling from the forging temperature.

Fracture—The irregular surface produced when a piece of metal is ruptured or broken.

Fracture Test—Breaking a piece of metal for the purpose of examining the fractured surface to determine the structure or carbon content of the metal or the presence of internal defects.

Free Ferrite—Ferrite formed from austenite on cooling, without simultaneous rejection of carbide.

Full Annealing—See annealing.

Fusible Alloys—A group of nonferrous alloys which melt at relatively low temperatures. They usually consist of bismuth, cadmium, lead, and tin in various proportions, and iron only as an impurity.

Gamma Iron—A crystal form of iron (face-centered cubic) stable between A_3 and A_4. See "Iron-Carbon Diagram," pages D-19-27.

Ghost, Ghost Lines, or Ghost Structure—See ferrite ghost.

Globular Cementite—See spheroidal cementite.

Grains—Individual crystals in metals.

Grain Growth—An increase in the grain size of metal.

Granular Pearlite (also globular pearlite and divorced pearlite)—A structure formed from ordinary lamellar pearlite by long annealing of steel at a temperature below but near to the lower critical point, causing the cementite to spheroidize in a ferrite matrix. Since "pearlite" connotes a lamellar structure, this name is not recommended; the word "spheroidite" has been proposed.

Granulation—The recrystallization of columnar crystals and dendrites in freshly solidified steel to more or less equiaxed grains at temperatures near the solidus.

Graphitizing—See annealing.

Hair Seam—See seam.

Hardening—Heating and quenching certain iron-base alloys from a temperature either within or above the critical temperature range for the purpose of producing a hardness superior to that obtained when the alloy is not quenched. Usually restricted to the formation of martensite.

Heat Tinting—Heating a specimen with a suitable surface in air for the purpose of developing the structure by oxidizing or otherwise affecting the different constituents.

Heat Treatment—An operation or combination of operations involving the heat-

ing and cooling of a metal or alloy in the solid state for the purpose of obtaining certain desirable conditions or properties.

Note—Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

Hot Shortness—Brittleness in metal when hot.

Hot Top—See sinkhead.

Hot Working—Plastic deformation of metal at a temperature high enough to prevent strain hardening.

Hypereutectoid Steel—A steel containing more than the eutectoid percentage of carbon; see eutectoid steel.

Hypoeutectoid Steel—A steel containing less than the eutectoid percentage of carbon; see eutectoid steel.

Inclusions—Particles of impurities, usually oxides, sulphides, silicates, and such which are mechanically held during solidification or which are formed by subsequent reaction of the solid metal.

Ingot—A special kind of casting for subsequent rolling or forging.

Ingot Iron—An open hearth iron very low in carbon, manganese, and other impurities.

Killed Steel—A steel sufficiently deoxidized to prevent gas evolution during solidification. The top surface of the ingot freezes immediately and subsequent shrinkage produces a central pipe. A semikilled steel, having been less completely deoxidized, develops sufficient gas evolution internally in freezing to replace the pipe by a substantially equivalent volume of rather deep-seated blowholes. (See section on Open Hearth Process.)

Lap—A surface defect appearing as a seam caused from folding over hot metal, fins, or sharp corners and then rolling or forging, but not welding, them into the surface.

Lap Weld—A term applied to a weld formed by lapping two pieces of metal and then pressing or hammering, particularly, to the longitudinal joint produced by a welding process for tubes or pipe in which the edges of the skelp are beveled or scarfed so that when they are overlapped they can be welded together. The product is known as lap weld or lap welded pipe.

Ledeburite—The cementite-austenite eutectic forming at point C on the iron-carbon diagram. During the cooling the austenite in ledeburite may transform to ferrite and carbide-cementite. It is found in cast iron and high alloy steels such as high speed steel.

Liquidus—The line on a temperature-composition (phase) diagram of a binary system, or surface on a diagram of a ternary system, representing the temperatures at which freezing begins on cooling or melting ends on heating under equilibrium conditions.

Lüder's Lines (stretcher-strains, flow figures)—Elongated surface markings that

appear on the surface of some materials, particularly iron and low carbon steel, when deformed just past the yield point. These markings lie approximately parallel to the direction of maximum shear stress and are the result of localized yielding. They consist of depressions when produced in tension and of elevations when produced in compression; they may be made evident by localized roughening of a polished surface or by localized flaking of scale from a scaled surface.

Lute—A mixture of fire clay used to seal up cracks between crucible and cover or between annealing box and cover to make a gas tight joint when heat is to be applied; also applied to the operation.

Macroscopic—Visible either with the naked eye or under low magnifications (up to about 10 diameters).

Macrostructure—The structure and internal condition of metals as revealed on a ground or polished (and sometimes etched) sample, by either the naked eye or under low magnifications (up to about 10 diameters).

Malleablizing—See annealing.

Martensite—A microconstituent or structure in quenched steel characterized by an acicular or needle-like pattern on the surface of polish. It has the maximum hardness of any of the decomposition products of austenite.

Note—Martensite is a transition lattice formed by the partial transformation of austenite. It is not an equilibrium lattice and thus not an equilibrium phase. The lattice is tetragonal.

Matrix—The ground mass or principal substance in which a constituent is embedded.

Mechanical Properties—Those properties that reveal the reaction, elastic and inelastic, of a material to an applied force, or that involve the relationship between stress and strain, for example, Young's modulus, tensile strength, fatigue limit. These properties have often been designated as physical properties, but the term mechanical properties is much to be preferred.

Mechanical Testing—Testing methods by which mechanical properties are determined.

Mechanical Working—Subjecting metal to pressure exerted by rolls, presses, or hammers, to change its form, or to affect the structure and therefore the mechanical and physical properties.

Metalloid—Originally a chemical element that has the physical characteristics of a metal such as metallic conduction and metallic luster, but which behaves chemically as both nonmetal and metal; that is, it reacts directly with other metals yet also combines with the halogens to form salts. Typical examples are arsenic, antimony, and tellurium. With increasing knowledge of metallic compounds the term has become less useful, and it is now considered obsolete. In metallurgical practice it has come to have a special meaning as applying to the elements such as C, Si, P, S, and Mn, which are commonly present in small amounts in iron and steel.

Modulus of Elasticity—The ratio, within the limit of elasticity, of the stress to the corresponding strain. The stress in pounds per square inch is divided by the elongation in fractions of an inch for each inch of the original gage length of the specimen.

Network Structure—A structure in which the grains or crystals of one constituent are partially or entirely surrounded with envelopes of another constituent. The appearance of an etched section through the crystals is that of a network.

Neumann Bands—Mechanical twins in alpha iron, in the form of narrow bands parallel to planes of the form (211). Customarily formed only on deformation by impact, but in some alloys (silicon-ferrite) and particularly at low temperatures formed more readily, as in ordinary cold working processes.

Nitriding—Adding nitrogen to iron-base alloys by heating the metal in contact with ammonia gas, or other suitable nitrogenous material.

> Note—Nitriding is conducted at a temperature usually in the range 935-1000°F., and produces surface hardening of the metal without quenching. See article on "Nitriding."

Normalizing—See annealing.

Overheating—Heating to such high temperatures that the grains have become coarse, thus impairing the properties of the metal.

Patenting—See annealing.

Pearlite—The lamellar aggregate of ferrite and carbide resulting from the direct transformation of austenite at Ar_1.

> Note—It is recommended that this word be reserved for the microstructures consisting of thin plates or lamellae—that is, those that may have a pearly luster in white light. The lamellae can be very thin and resolvable only with the best microscopic equipment and technique.

Permanent Mold—A mold ordinarily of metal which is used repeatedly for the production of many castings of the same form. Not commonly applied to ingot molds.

Permanent Set—Permanent deformation.

Phosphorus Banding—See ferrite ghost.

Physical Properties—Those properties familiarly discussed in physics, exclusive of those described under mechanical properties; for example, density, electrical conductivity, coefficient of thermal expansion. This term has often been used to describe mechanical properties, but this usage is not recommended. (See mechanical properties.)

Physical Testing—Testing methods by which physical properties are determined. This term is also inadvisedly used to mean the determination of the mechanical properties.

Piercing—Producing a hole in metal by forcing an instrument through it. Usually refers to making steel tubes from solid steel bars.

Pig Iron—Pig Iron is the product of the blast furnace and is made by the reduction of iron ore. With the exception of direct metal, pig iron is either remelted and cast (producing gray and white iron), or it is refined in the steel making processes. (Some special pig irons are blast furnace products diluted in carbon and silicon content by the addition of molten steel to the molten blast furnace product.)

Pine Tree Crystals—See dendrite.

Pinhead Blister—See blister.

Pipe—A cavity formed in metal (especially ingots) during the solidification of the last portion of liquid metal. Contraction of the metal causes this cavity or pipe

Pit—A sharp depression in the surface of metal.

Pot Annealing—See box annealing.

Pouring—Pouring molten metal from the ladle into ingot molds or other types of molds (as, for example, in castings).

Process Annealing—See annealing.

Quaternary Alloy—An alloy containing four principal elements.

Quenching—Rapid cooling by immersion in liquid or gases or by contact with metal.

Recalescence—The liberation of heat when steel is cooling through Ar_1 point.

Red Shortness—Brittleness in steel when it is red hot.

Reduction in Area—The difference between the original cross sectional area and that of the smallest area at the point of rupture. It is usually stated as a percentage of the original area; also called "contraction of area."

Refining Temperature or Heat—A temperature employed in heat treatment to refine the structure, in particular, the grain size. Usually just above Ac_3 in steel.

Regenerative Quenching—A double quenching of carburized objects to refine the case and core. The first quench is from a high temperature to refine the core, and the second quench is from a lower temperature to further refine and harden the case.

Rimmed Steel—An incompletely deoxidized steel normally containing less than 0.25% carbon and having the following characteristics: (a) During solidification an evolution of gas occurs sufficient to maintain a liquid ingot top ("open" steel) until a side and bottom rim of substantial thickness has formed. If the rimming action is intentionally stopped shortly after the mold is filled the product is termed *capped steel.* (b) After complete solidification, the ingot consists of two distinct zones: A rim somewhat purer than when poured and

a core containing scattered blowholes with a minimum amount of pipe and having an average metalloid content somewhat higher than when poured and markedly higher in the upper portion of the ingot.

Riser—See sinkhead.

Scab (Scabby)—A rough projection on a casting caused by the mold breaking or being washed by the molten metal; or occurring where the skin from a blowhole has partly burned away and is not welded.

Scarfing—See chipping.

Seam—A crack on the surface of metal which has been closed but not welded; usually produced by blowholes which have become oxidized. If very fine, a seam may be called a hair crack or hair seam; also see *cold shut* and *lap.*

Secondary Hardening—Hardness developed by tempering high alloy steels.

Self Hardening Steel—A steel carrying sufficient carbon or alloy content (or both) to form martensite through rapid heat removal from a locally heated portion (as in welding) by conduction into the surrounding cold metal. See also *air hardening.*

Semifinished—See finished.

Sheet Bar—See bloom.

Shortness—Brittleness in metal.

Silky Fracture—A steel fracture having a very smooth fine grain or silky appearance.

Sinkhead or Hot Top (also called a Riser when applied to castings)—A heat insulated reservoir for excess metal on top of an ingot mold or casting mold which feeds the shrinkage of the ingot or the casting.

Skelp—A plate of steel or wrought iron from which pipe or tubing is made. This is done by rolling the skelp up longitudinally into shape and welding or riveting the edges together.

Slab—See bloom.

Slabbing Mill—A heavy plate mill usually of the two-high universal type.

Slip Bands—A series of parallel lines running across a crystalline grain and produced by deforming the body after the surface on which these lines appear has been polished. They are traces of the slip planes, or planes joining the displaced crystalline blocks or lamellae, and may be distinguished from twin markings by repolishing and etching: Twin markings will reappear, but slip lines will not.

Slip Plane—See slip bands.

Soaking—Holding steel at an elevated temperature for the attainment of uniform temperature throughout the piece.

Solidification Range—Temperature range through which metal freezes or solidifies.

Solidus Line—The line on a phase diagram below which (at lower temperature) the alloy is entirely solid under equilibrium conditions.

Sonims—Solid nonmetallic inclusions in a metal or alloy.

Sorbite—A late stage in the tempering of martensite, when the carbide particles have grown so that the structure has a distinctly granular appearance. Further and higher tempering causes globular carbides to appear clearly.

Note—Many times the term sorbite is erroneously given to an imperfectly developed pearlite or mixed structure in steel.

Spalling—The cracking and flaking of small particles of metal from the surface.

Spheroidal or Spheroidized Cementite—The globular condition of iron carbide resulting from a spheroidizing treatment (see under annealing). The initial structure may be either pearlitic or martensitic.

Note—The term "spherodized pearlite" should be avoided, even when the structure is undoubtedly the result of spheroidizing anneal of a pearlite steel. The term "spheroidite" has been proposed.

Spheroidizing—See annealing.

Spiegel (also Spiegeleisen—A pig iron containing 15-30% manganese and 4.5-6% carbon.

Stead's Brittleness—A condition of brittleness yielding rectangular transcrystalline fractures in the coarse grain structure produced by prolonged annealing of thin sheets of very low carbon steel previously rolled at a relatively low temperature (below 1300°F.).

Tapping—Removing molten steel from the melting furnace by opening the tap hole and allowing the steel to run into the ladle.

Teeming—See pouring. Usually refers to pouring of metal into molds.

Tempering—See annealing.

Temper Carbon—A form of graphite in iron-base alloys produced by heating below the melting point.

Ternary Alloy—An alloy containing three principal elements.

Troostite—A microconstituent of hardened and tempered steel which etches rapidly and therefore usually appears dark. It consists of a very fine aggregate of ferrite and cementite and is not resolved under the microscope.

Note—Two entirely different structures are frequently confused and called troostite. The nodular quick etching microconstituent, found in steels which are cooled just too slowly to be fully martensitic, can be resolved into very fine pearlite. It is recommended that the use of the term troostite or "quenching or nodular troostite" to denote this structure be avoided. "Temper troostite" is the first product of the tem-

pering of martensite and consists of submicroscopic particles of carbide in ferrite, and is frequently indistinguishable in general appearance from a quickly etching fine pearlite. If the word troostite is to be retained it should be reserved for temper troostite. It changes on higher tempering by indistinguishable degrees into sorbite.

Twin Crystals (twins, twinned crystals)—A crystal grain in which the crystal lattices of two parts are related in orientation to each other as mirror images across the interface, which is known as the twinning plane.

Twin Bands—In a polished and etched section, a band across a crystal grain, brought by twinning into relation with the main body of the grain as described above.

Widmanstätten Structure—When a new solid phase forms from a parent solid phase, such as ferrite from austenite, the new phase generally develops plates parallel to lattice planes of a single form in the parent phase, for example, the four families of octahedral planes in austenite. On the polished and etched surface the traces of these plates intersect in a geometrical pattern. Needles and polyhedra may also form. The orientation of the lattice in the new phase is related crystallographically to the orientation of the lattice in the parent phase. Familiarly seen in cast steel and in overheated wrought steel when cooled rather rapidly, but may occur in any alloy in which a phase change occurs.

Wire Rod—A semifinished product from which wire is made. It is generally of circular cross section approximately 7/32 to 3/4 inch in diameter.

Woody Fracture—A descriptive term for fracture of sound though dirty steel, frequently also reedy or conchoidal in appearance, and often containing discernible slag particles. Woody fractures sometimes contain many small silvery areas, too numerous and small to be correctly termed "flakes," and of a different nature.

Work Hardness—Hardness developed in metal resulting from cold working.

Yield Point—The load per unit of original cross section at which, in soft steel, a marked increase in deformation occurs without increase in load. In other steels and in nonferrous metals, "yield point" is the stress corresponding to some definite and arbitrary total deformation, permanent deformation or slope of the stress deformation curve; this is more properly termed the yield strength.

Yield Strength—Stress corresponding to some fixed permanent deformation such as 0.1 or 0.2% offset from the modulus scope.

Young's Modulus—See modulus of elasticity.

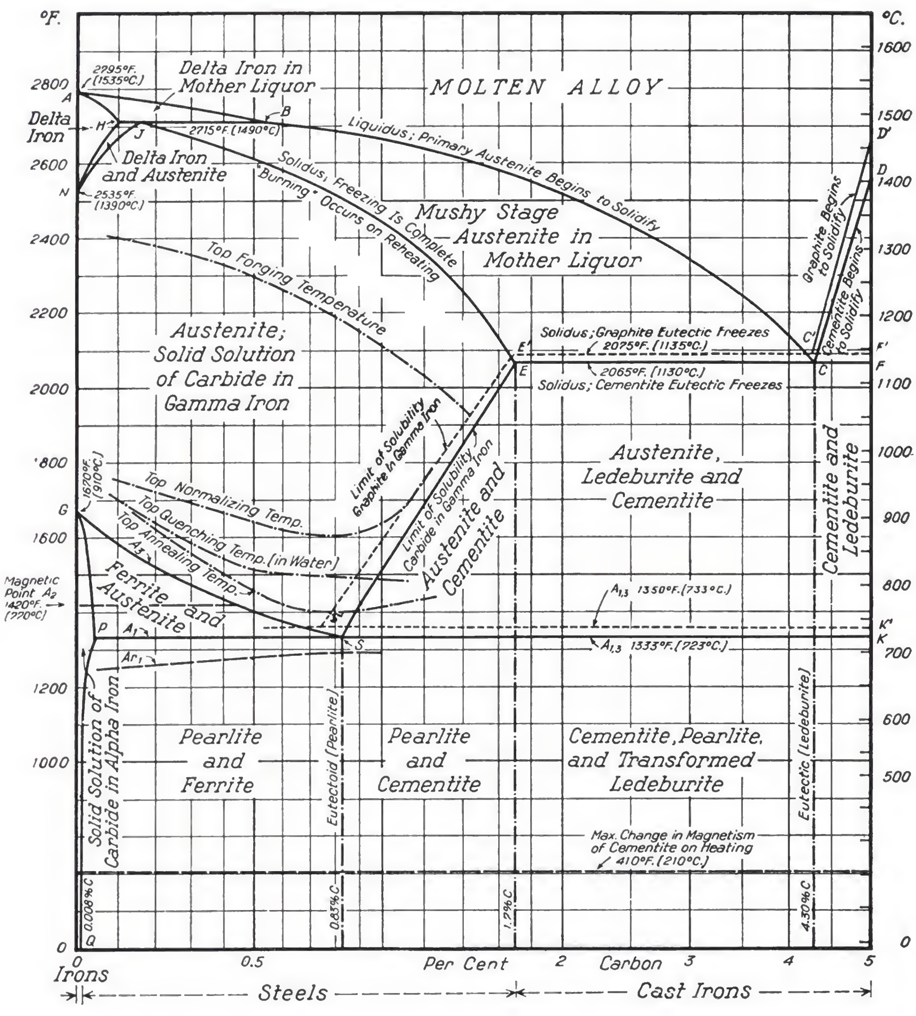
Specific Effects of Alloys in Steel

Element	Solid Solubility		Influence Upon Ferrite	Influence Upon Austenite (Hardenability)	Influence Exerted Through Carbide		Principal Functions
	In Gamma Iron	In Alpha Iron			Carbide Forming Tendency	Action During Tempering	
Aluminum Al	1.1% (Increased by C)	30% ±	Hardens considerably by solid solution	Increases hardenability mildly, if dissolved in austenite	Less than Fe (Graphitizes)	......	1. Deoxidizes efficiently. 2. Restricts grain growth (by forming dispersed oxides or nitrides) 3. Alloying element in nitriding steel
Chromium Cr	12.8% (20% with 0.5% C)	Unlimited	Hardens slightly; increases corrosion resistance	Increases hardenability moderately, similarly to manganese	Greater than Mn; Less than W	Mildly resists softening	1. Increases corrosion and oxidation resistance 2. Increases hardenability 3. Adds some strength at high temperatures 4. Resists abrasion and wear (with high carbon)
Cobalt Co	Unlimited	80% ±	Hardens considerably by solid solution	Decreases hardenability as dissolved	Similar to Fe	Sustains hardness by solid solution	1. Contributes to red hardness by hardening ferrite
Manganese Mn	Unlimited	15 to 18%	Hardens markedly; reduces plasticity somewhat	Increases hardenability moderately, similarly to chromium	Greater than Fe; Less than Cr	Very little, in usual percentages	1. Counteracts brittleness from the sulphur 2. Increases hardenability inexpensively 3. Forms better resistant steel (high Mn, high C)
Molybdenum Mo	3% ± (8% with 0.3% C)	32%, (Less with lowered temperature)	Provides age-hardening system in high Mo-Fe alloys	Increases hardenability strongly (Mo > Cr)	Strong; Greater than Cr	Opposes softening, by secondary hardening	1. Raises coarsening temperature of austenite 2. Deepens hardening 3. Raises hot and creep strength, red hardness 4. Enhances corrosion resistance in stainless 5. Forms abrasion-resisting particles
Nickel Ni	Unlimited	25% ± (Irrespective of carbon content)	Strengthens and toughens by solid solution	Increases hardenability mildly, but tends to retain austenite with higher carbon	Less than Fe (Graphitizes)	Very little in small percentages	1. Strengthens unquenched or annealed steels 2. Toughens pearlitic-ferritic steels (especially at low temperature) 3. Renders high chromium-iron alloys austenitic
Phosphorus P	0.5%	2.5% (Irrespective of carbon content)	Hardens strongly by solid solution	Increases hardenability, similarly to manganese	Nil	......	1. Strengthens low carbon steel 2. Increases resistance to corrosion 3. Improves machinability in free-cutting steels
Silicon Si	2% ± (9% with 0.35% C)	18.5%, (Not much changed by carbon)	Hardens with loss in plasticity (Mn < Si < P)	Increases hardenability more than nickel (Ni < Si < Mn)	Negative (Graphitizes)	Sustains hardness by solid solution	1. Used as general purpose deoxidizer 2. Alloy for electrical and magnetic sheet 3. Improves oxidation resistance 4. Increases hardenability of steels carrying non-graphitizing elements 5. Strengthens low alloy steels
Titanium Ti	0.75% (1% ± with 0.20% C)	6% ±, (Less with lowered temperature)	Provides age-hardening system in high Ti-Fe alloys	Probably increases hardenability very strongly, *as dissolved*. Its carbide effects reduce hardenability	Greatest known (2% Ti renders 0.50% carbon steel unhardenable)	Persistent carbides probably unaffected. Some secondary hardening	1. Fixes carbon in inert particles (a) Reduces martensitic hardness and hardenability in medium chromium steels (b) Prevents formation of austenite in high chromium steels (c) Prevents localized depletion of chromium in stainless during long heating
Tungsten W	6% (11% with 0.25% C)	32%, (Less with lowered temperature)	Provides age-hardening system in high W-Fe alloys	Increases hardenability strongly in small amounts	Strong	Opposes softening by secondary hardening	1. Forms hard, abrasion resistant particles in toolsteels 2. Promotes red hardness and hot strength
Vanadium V	1.5% ± (4% with 0.20% C)	Unlimited	Hardens moderately by solid solution	Increases hardenability very strongly, *as dissolved*	Very strong (V < Ti or Cb)	Maximum for secondary hardening	1. Elevates coarsening temperature of austenite (promotes fine grain) 2. Increases hardenability (when dissolved) 3. Resists tempering and causes marked secondary hardening

Revised, 1942. Adapted from "The Functions of the Alloying Elements in Steel" by Edgar C. Bain; published by

IRON, IRON-CARBON EQUILIBRIUM DIAGRAM

Approximate Iron-Graphite Diagram in Dotted Line



Except as noted hereafter, lines are reproduced by courtesy of The Engineering Foundation from diagrams published in one of the Alloys of Iron Monographs: "Alloys of Iron and Carbon," Vol. I on Constitution, by Samuel Epstein.

Delta iron region and solidus by Frank Adcock, *Journal* of the Iron and Steel Institute, 1937-I.

Forging and heat treating temperatures from Recommended Practices, 1939 A.S.M. Metals Handbook.

Solidus in Iron-Graphite System according to Kaya, Honda and Endo, *Science Reports*, Tohoku Imperial University, 1925 and 1927.

Ar_1 according to Hoyt and Dowdell, "Metals and Common Alloys," for cooling rates of 1° C. in 3 sec.

Line GPQ according to J. H. Whiteley, *Journal*, Iron and Steel Institute, 1936.

Source—Metal Progress.

CONSTITUTION OF IRON-CARBON ALLOYS

By R. S. Archer

Cementite—Iron and carbon form a hard, brittle, crystalline compound, the composition of which is represented by the formula Fe_3C. This compound is referred to as iron carbide, or cementite. It contains 6.68% carbon by weight. Cementite crystallizes in the orthorhombic system, the unit cell containing 4 Fe_3C groups. The lattice parameter has been determined by Westgren and Phragmen,[1] by Wever,[2] and by Shimura[3] on cementite crystals obtained from spiegeleisen. (The crystals probably contained some manganese and were, therefore, not pure iron carbide). The average values reported by these investigators are: $a_o = 4.51$ Å; $b_o = 5.06$ Å; $c_o = 6.74$ Å. The average value for density corresponding to these determinations is 7.73, which is in good agreement with the value 7.74 obtained by Benedicks and 7.66 by Honeyman. The positions of the iron and carbon atoms in the cementite crystal as determined by Hendricks from the data of Westgren and Phragmen have been accepted by Westgren[5] as probably correct. On heating above 1100°C., iron carbide decomposes rapidly to iron and graphite. Its melting point has therefore not been observed but has been estimated at about 2000°C. Cementite undergoes a magnetic transformation at about 200°C.,[6] designated A_0.

Graphite—Under certain conditions, some of the carbon of iron-carbon alloys is present in the form of graphite, which is a distinct crystalline modification of the element carbon. Graphite is soft and friable. Graphite formed by annealing, as in malleable castings, is commonly referred to as temper carbon.

Allotropy of Iron— Solid iron is crystalline in structure, belonging to the cubic system. There are two distinct crystalline modifications of iron which are distinguished from each other by the arrangement of the atoms within the crystals. Each modification is stable only within certain ranges of temperature.

Modification	Crystal Structure	Range of Stability, °C.
Delta	Body-Centered Cubic	1535-1400
Gamma	Face-Centered Cubic	1400- 910
Alpha	Body-Centered Cubic	910 and below

The appearance of the new crystalline form on heating or cooling through one of the critical temperatures is accompanied by complete recrystallization.

Iron undergoes certain discontinuous changes in physical properties in the neighborhood of 770°C. In particular, there is a marked decrease in magnetic properties on heating, this change being completed at 775°C.[6] A slight evolution of heat on cooling, and a corresponding absorption on heating reach maximum intensity at 768°C. These changes are not accompanied by a change in crystal structure or by any corresponding phase change in the iron-carbon alloys.

Metallic Solid Solutions—Many metals possess the ability to dissolve certain other elements in the solid state, forming solid solutions which in many ways are analogous to ordinary liquid solutions. Ordinary brass, for example, is a solid solution of zinc in copper. Among the distinguishing characteristics of metallic solid solutions are: (1) Absence of definite atomic proportions; (2) capacity for change in chemical composition without abrupt change in physical properties; (3) ability of the dissolved elements to diffuse under suitable temperature conditions; (4) attainment of physical and chemical homogeneity when sufficient opportunity for diffusion is allowed.

It is probable that all metallic solid solutions are characterized by the atomic dispersion of the dissolved elements. When the atomic volumes of the solvent and solute elements are similar, as in the case of iron and nickel, it seems that the solute atoms replace atoms of the solvent, the space-lattice of which is retained. When the solute atom is markedly smaller than the solvent atom, as in the case of carbon and iron, it is quite probable that the solute atoms are in between atoms of the solvent.

Ferrite—Alpha iron is capable of holding in solid solution considerable amounts of various elements, such as nickel, silicon, and phosphorus. The maximum solu-

---

Source—A.S.M. Metals Handbook, 1939 Edition.

bility of carbon in alpha iron occurring at 723°C. (1333°F.) is approximately 0.035%.[7, 8, 9] This decreases as the temperature falls to less than 0.01%[10, 11] at room temperature. The varying solubility of carbon in alpha iron although slight, as shown by these figures, has appreciable effects on the properties of the iron-carbon alloys.

The term *"ferrite"* is applied to solid solutions in which alpha iron (or delta iron) is the solvent.

Austenite—Solid solutions in which gamma iron is the solvent are called **austenite.** Gamma iron dissolves carbon to a great extent. The maximum solubility at 2066°F. is 1.7%. This decreases with temperature to 0.80% at 1333°F.

Constituents and Phases—Those portions of an alloy which under the microscope appear to be definite units in the structure are called constituents. Thus the constituents of an annealed low carbon steel are ferrite and pearlite. Usually the term constituent is only applied to a portion of the alloy which appears homogeneous. Pearlite appears homogeneous at low magnifications, but at higher magnifications it is seen to be a mixture of alternate plates of ferrite and cementite. Another constituent, troostite, appears homogeneous at all except very high magnifications, at which it is seen to be similar in structure to pearlite but much finer. Sometimes the term constituent is applied to structural bodies which are easily seen to be mixtures, even at low magnifications. This is true of the austenite-cementite eutectic, called Ledeburite.

A phase is a portion of an alloy, physically and chemically homogeneous throughout, which is separated from the rest of the alloy by distinct bounding surfaces. The following phases ocur in the iron-carbon alloys: Molten alloy, austenite, ferrite, cementite, and graphite. It will be noted that any of these phases may likewise be called a constituent. Not all constituents are phases, however, since some are mixtures and are not "physically and chemically homogeneous throughout."

Constitution—The constitution of an alloy is completely described when we state what phases are present and how much of each. The question of the arrangement of these phases is not involved. It is a sufficient description of the constitution of an annealed low carbon steel at room temperature, for example, to say that it contains 3% cementite and 97% ferrite, although a description of the structure of this steel might give the added information that it contains about 22% of pearlite and 78% of free ferrite.

The iron-carbon diagram deals only with the constitution of the iron-carbon alloys and not with their structure.

Equilibrium—The iron-carbon diagram represents alloys in a condition of equilibrium. It may be considered that a state of equilibrium exists in an alloy at any given temperature where exposure to that temperature for any further period of time does not produce any change in constitution, provided the temperature in question is sufficiently high to allow constitutional changes to go to completion. The test of equilibrium is that the same condition is reached, no matter from which side it is approached, whether heating or cooling.

How Diagram Is Plotted—In Fig. 1 the temperature is plotted vertically and composition horizontally. Any point in the diagram represents a definite alloy at a definite temperature. The carbon content of the alloy is shown on the horizontal axis directly below the point in question, while the temperature is shown on the vertical axis directly opposite the point.

The various lines of the iron-carbon diagram represent phase changes, as will now be described.

The Liquidus—The line "ABCD," called the liquidus, represents the beginning of solidification on cooling and the end of melting on heating. All points above this line represent alloys in a completely molten condition. All points below ABCD represent alloys partially or completely solid.

Solidification—Alloys containing from 0-0.55% carbon begin to solidify on cooling to the line AB by the separation from the liquid of crystals of delta iron containing in solid solution an amount of carbon indicated by the line AH. By this separation of delta iron, the melt is enriched in carbon until the peritectic line HJB is reached. If the composition is to the left of J, delta of composition H will undergo a peritectic reaction with the melt of composition B resulting in the solidification of austenite of composition J, and the amount of delta of composition H will be thus reduced. On further cooling to the line NJ, the delta ferrite will transform to austenite. If the composition is to the right of J, the delta of composition

H will transform to austenite of composition J and reduce slightly the amount of the melt of composition B. On cooling to JE, the molten phase will solidify to austenite. Alloys containing from 0.55-4.3% carbon begin to solidify on cooling to the line BC by the separation of austenite crystals from the liquid.

Alloys containing more than 4.3% carbon begin to solidify with the separation of cementite from the liquid, on cooling to the line CD.

The alloy containing 4.3% carbon is the eutectic alloy and solidifies entirely at the point C, with the simultaneous formation of austenite and cementite.

In the case of alloys containing 0.55-1.7% carbon, austenite continues to freeze out on cooling from JBG to JE. At JE the alloy is completely solid and consists of one phase, austenite.

In alloys containing from 1.7-4.3% carbon, austenite freezes out of the liquid from BC to EC. At EC there is some residual liquid, which is of eutectic composition. This liquid then solidifies at constant temperature, forming the eutectic mixture of austenite and cementite.

In alloys containing more than 4.3% carbon, cementite freezes out on cooling from CD to CF. At CF the residual liquid is of eutectic composition and solidifies at constant temperature.

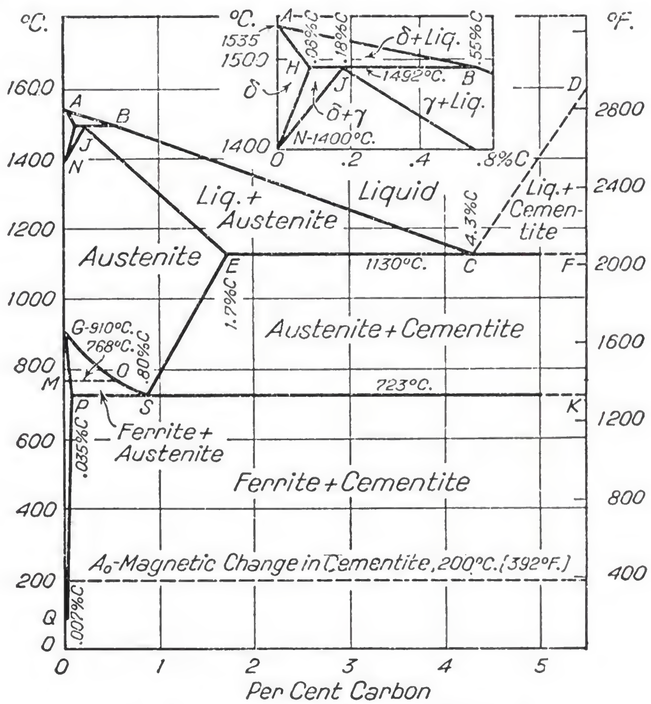


Fig. 1—Iron-Carbon Constitution Diagram.

The Solidus—The line AHJEF is called the solidus. Below this line all alloys are completely solid.

Ferrite Solubility Curve—The temperature at which alpha iron forms from gamma iron on cooling is lowered by the presence of carbon in solid solution in the gamma iron, that is, in austenite. This is represented in the diagram by the line GS, which shows that the temperature of formation of ferrite decreases from 1670°F. for pure iron to 1333°F. for an alloy containing 0.80% carbon. The formation of ferrite from the solid solution austenite is analogous to the precipitation of a salt from its solution in water. The line GS thus expresses the solubility of ferrite in austenite, and may be referred to as the **ferrite solubility curve.**

The dotted line MO represents the discontinuous change in the physical properties of alpha iron at about 768°C. It does not represent a phase change in the

iron-carbon alloys. The thermal arrest occurs at MO, and in alloys of higher carbon content is merged with the other arrests corresponding to the line OSK. Some diagrams show a sharp break in the ferrite solubility curve GOS at the point O. There seems to be sufficient evidence that GOS should be slightly curved, as shown in Fig. 1, but a sharp break at the point O is questionable. When austenite containing less than 0.80% carbon is cooled to temperatures represented by the line GOS, ferrite separates from solution. Since the ferrite is almost carbon-free iron, its separation results in an enrichment of the remaining austenite in carbon. This causes a progressive lowering of the temperature at which ferrite separates out, and the austenite constantly diminishes in amount and becomes richer in carbon. Consider a steel containing 0.40% carbon. At 1650°F. this steel consists entirely of austenite. On cooling to about 1435°F. ferrite begins to form, and continues to separate from the austenite as the steel cools further. When a temperature of 1333°F. is reached, the steel consists of one-half ferrite containing practically no carbon and one-half austenite containing 0.80% carbon.

Cementite Solubility Curve—At the eutectic temperature, 2066°F., austenite will hold 1.7% of carbon in solid solution. When austenite of this composition is cooled, cementite precipitates from solution. The solubility of carbon in austenite at various temperatures is shown by the line SE, which may be called the **cementite solubility curve,** as cementite is the phase which is precipitated.

When a steel containing more than 0.80% carbon is cooled from a temperature at which it is austenitic, cementite begins to deposit at the line SE. Since cementite contains 6.68% carbon, its precipitation causes a lowering of the carbon content of the austenite. This lowers the temperature at which cementite precipitates, and the cooling of the steel results in a progressive precipitation of cementite and a progressive decrease in the carbon content of the austenite. This continues until a temperature of 1333°F. is reached, and the residual austenite then contains 0.80% carbon.

The Eutectoid—No matter what carbon content is started with, austenite reaches a temperature of 1333°F. on slow cooling with a carbon content of 0.80%.

On cooling through this temperature austenite containing 0.80% carbon deposits simultaneously a mixture of ferrite and cementite. This mixture is called the **eutectoid,** from analogy to the eutectic.

The eutectoid temperature 1333°F. is the temperature at which austenite is simultaneously saturated with both ferrite and cementite. This is represented in the diagram by the intersection of the ferrite solubility curve GS with the cementite solubility curve SE, at the eutectoid point S.

Pearlite—With moderately slow cooling, the decomposition of austenite containing 0.80% carbon results in the formation of a constituent in which the ferrite and cementite occur as alternate thin lamellae. These lamellae refract light in a similar manner to the lines of a diffraction grating, giving the constituent a pearly appearance, from which it has received the name **pearlite.**

Reversibility of Phase Changes—The phase changes which occur on cooling, as described above, are reversed on heating. For example, on heating pearlite through 1333°F. the ferrite and cementite redissolve to form austenite. Considering the 0.40% carbon steel again, we have at room temperature a mixture of approximately equal parts of ferrite and pearlite. On heating to the line PSK (Fig. 1) this pearlite changes at constant temperature to austenite of eutectoid composition; the ferrite is unaffected.* On heating above PSK the ferrite **gradually** dissolves in the austenite until all of the ferrite is dissolved on crossing the line GS, and the austenite contains 0.40% carbon.

The Critical Points—The phase changes described liberate heat when they take place on cooling, and absorb heat on heating. These evolutions and absorptions of heat are shown by halts or arrests in cooling curves and heating curves, which indicate the temperatures at which the changes take place, and are usually called the **critical points.**

The method of designating the various points, which is borrowed from the French, needs a word of explanation. The halt or "arrest" in cooling or heating is designated by the letter A, standing for the French word arrêt. An arrest on cooling is referred to by the letters Ar, r standing for **refroidissement** = cooling. An arrest on heating is designated by the letters Ac, the c standing for **chauffage** = heating. The

*Except for dissolving the traces of carbon soluble below A1.

various arrests are distinguished from each other by numbers after the letters, being numbered in the order in which they occur as the temperature increases, as follows:

Arrest	Temp. °F.	Significance
A0	390	A magnetic change in cementite. Probably not a phase change. Hence shown in diagram by dotted line.
A1	1333	The eutectoid transformation.
A2	1414	A change in the magnetic and certain other properties of alpha iron. Not a phase change.
A3	1333-1670	The beginning of the precipitation of ferrite from austenite on cooling, or the end of its solution on heating.
A4	2552 (in pure iron)	The change from gamma to delta iron on heating, and vice versa on cooling.

When the critical point or the recalescent point is mentioned, it is usually the temperature of the eutectoid transformation, A1, that is meant.

Lag—The temperatures given above and in the diagram refer to conditions of equilibrium. Under practical conditions there is a delay or lag in the attainment of equilibrium, and the critical points are found at lower temperatures on cooling, and at higher temperatures on heating, than those given. That is, there is a difference between the Ar points and the Ac points. This difference increases with the rate of cooling or heating. The equilibrium temperatures correspond to very slow cooling or heating.

Classification of Alloys—Steels containing less than 0.80% carbon are called **hypoeutectoid** steels. Steel containing approximately 0.80% carbon is called **eutectoid** steel, or steel of eutectoid composition. Steels containing more than this amount of carbon are called **hypereutectoid.** Alloys containing less than 4.3% carbon are **hypoeutectic alloys;** alloys containing more than 4.3% carbon are **hypereutectic alloys.** The alloy containing 4.3% carbon is the **eutectic** alloy.

Phase Fields—While the various lines of the constitution diagram represent phase changes, the areas bounded by these lines represent conditions of temperature and composition under which certain phases are stable. The phases stable within the various fields of the diagram are as follows:

Above ABCD	Liquid Solution	DCF	Cementite + Liquid
AHB	Delta + Liquid	NJESG	Austenite
AHN	Delta Iron Solid Solution	GSP	Ferrite + Austenite
HJN	Delta + Gamma	ESKF	Cementite + Austenite
JBCE	Gamma + Liquid	Under PSK	Ferrite + Cementite
		GPQ	Alpha Ferrite

Proportions of Phases—The amount of a certain phase present in a given alloy at a given temperature can be calculated in accordance with the following principle and examples: Determine the number of units on the composition axis between the points at which the alloy consists entirely of the phase in question, that is, the point at which the quantity of this phase is 100%, and the point at which the quantity of this phase has just decreased to 0.00%. Represent this number of units by the letter M. Determine the number of units on the composition axis between the composition of the alloy in question, and the point at which there is 0.00% of the desired phase. Represent this number by the letter N. Then the amount x of the desired phase, expressed in per cent, is

$$x = \frac{N}{M} \times 100$$

If the compositions expressed by the letters "M" and "N" are in weight percent, then the amount "X" of the desired phase will also be in weight percent. In the case of the iron-carbon alloys, however, the density of cementite is so close to that of iron, that "X" will also closely represent the volume percentage of the desired phase. In alloys whose constituents differ markedly from each other in density, a more general method of calculation must be employed which takes into account the densities of the various constituents.

For example, it is desired to calculate the amount of cementite in the austenite-cementite eutectic immediately after solidification; that is, at the eutectic temperature. With 6.68% carbon the alloy is 100% cementite. As the carbon is decreased the

amount of cementite decreases, becoming zero at 1.70% carbon, which is the amount soluble in iron at this temperature. The quantity M referred to above is then 6.68—1.70=4.98. The eutectic alloy is 4.30—1.70=2.60 units from the point of zero cementite. Then

$$\frac{2.6}{4.98} \times 100 = 52\% \text{ cementite in the eutectic alloy,}$$

$$100 - 52 = 48\% \text{ austenite in the eutectic alloy.}$$

Description of Phases According to Origin—The austenite that freezes out of hypoeutectic alloys above the eutectic temperature is usually distinguished as **primary austenite.** The austenite of the austenite-cementite eutectic is referred to as **eutectic austenite.** Likewise, the cementite which freezes out of alloys containing more than 4.3% carbon is called **primary cementite,** and the cementite of the eutectic is called **eutectic cementite.** The ferrite which forms from hypoeutectoid austenite at GS is called **proeutectoid ferrite,** and the cementite which precipitates along SE is **proeutectoid cementite.** The ferrite and cementite of the eutectoid itself are described as **eutectoid** or **pearlitic.** Thus there are two kinds of ferrite from the structural standpoint, and four kinds of cementite distinguished by their origin.

Structural Constitution—The quantities of the structural constituents present in an alloy can also be calculated with the help of the equilibrium diagram, using the principle illustrated above.

Suppose it is desired to calculate the amount of pearlite in a 0.35% carbon steel at room temperature. The carbon content corresponding to 100% pearlite is 0.80%. Assuming that the solubility of carbon in iron at room temperature is zero, which is practically the case, the point at which the amount of pearlite decreases to zero is 0.00% carbon. Then M = 0.80 — 0.00 = 0.80.

$$N = 0.35 - 0.00 = 0.35$$

The amount of pearlite in the steel

$$= \frac{N}{M} \times 100 = \frac{0.35}{0.80} \times 100 = 44\%$$

The amount of ferrite in the steel = 100 — 44 = 56%.

A steel containing 1.7% carbon, after cooling at a normal rate to room temperature, is composed of pearlite and proeutectoid cementite. The amount of this cementite can be calculated as follows: The carbon content at which the structure would consist entirely of cementite is 6.68% (the composition of pure cementite). The carbon content at which the proeutectoid cementite decreases to zero is 0.80%. Then M = 6.68 — 0.80 = 5.88. N = 1.70 — 0.80 = 0.90. The quantity of proeutectoid cementite in the 1.70% carbon steel is then

$$\frac{N}{M} \times 100 = \frac{0.90}{5.88} \times 100 = 15\%$$

The amount of pearlite in the steel is 100 — 15 = 85%. Since 1.7% carbon is the maximum amount soluble in austenite, 15% is the maximum amount of proeutectoid cementite possible.

Effect of Other Elements—All commercial steels contain more or less manganese, phosphorus, sulphur and silicon. Most commercial steel also contains residual amounts of copper and nickel. The data on temperature and composition which are represented in the iron-carbon diagram refer to iron-carbon alloys containing extremely low amounts of other elements. The amounts of these other elements which are present in commercial steel may alter appreciably the location of the various lines in the diagram. When still larger amounts are present, even the form of the diagram may be substantially changed. The constitutions of various binary alloys of iron are discussed in the articles immediately following this one. It is hoped that it will later be possible to present complete data on the constitution of the ternary alloy systems comprising iron, carbon and one other element. The effect

of this other element on the constitution of the iron-carbon alloys will then be completely described.

Stable vs. Metastable Equilibrium—Under certain conditions the carbon of iron-carbon alloys occurs as graphite. This is favored by extremely slow cooling, a condition which in general favors the establishment of stable equilibrium. It is, therefore, generally considered that iron and graphite represent the ultimately stable phases of the iron-carbon system, and that the occurrence of iron and cementite represents metastable equilibrium. Accordingly, alloys which at various temperatures consist of austenite and graphite, or of ferrite and graphite, with no cementite, are said to constitute the **stable system.** Alloys containing cementite but no graphite, which have been described above, are said to constitute the **metastable system.**

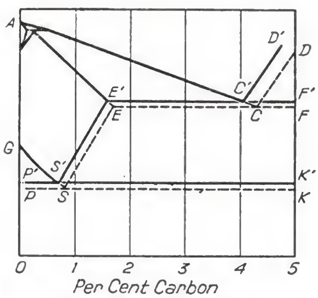


Fig. 2—Stable and Metastable Equilibrium Diagrams. The Dotted Lines Represent Metastable Equilibrium and the Solid Lines Represent Stable Equilibrium. For simplicity, some details which are not pertinent to the iron-graphite system are omitted from this diagram (see Fig. 1).

Phases of Stable System—The phases of the stable system are: (1) Liquid alloy; (2) austenite; (3) ferrite; and (4) graphite. It will be noted that the first three of these also occur in the metastable iron-cementite system.

Effect of Composition on Graphitization—The formation of graphite is favored by the presence of silicon, nickel and aluminum. In practice it is difficult to produce graphite in strictly pure iron-carbon alloys. The occurrence of graphite in such products as gray cast iron, malleable iron, and tool steel is usually due to the presence of silicon.

Graphitization is opposed by the presence of carbide forming elements such as chromium and manganese. Sulphur as iron sulphide strongly opposes graphitization, but is inactive when present as manganese sulphide. The first additions of manganese, therefore, favor graphitization by neutralizing sulphur. For a given composition of alloy with respect to elements other than iron and carbon, graphitization takes place more readily the higher the total carbon.

Diagram for Stable System—The constitution diagram of the iron-graphite system is shown in Fig. 2 in full lines, the dotted lines representing the equilibria of the iron-cementite system.

In the case of three lines, AC, AE, and GS, the dotted lines and full lines coincide. This is because these lines represent equilibria between those three phases which are common to the two systems.

The rest of the diagram, in which the dotted lines and full lines do not coincide, merely expresses the fact that at all temperatures the solubility of graphite in iron is less than that of cementite in iron. Accordingly the eutectic and eutectoid temperatures of the iron-graphite system are higher than for the iron-cementite system.

The diagram is qualitative in that it does not represent the exact differences in solubility and temperature. These differences are relatively slight. Wells[12] has made careful determinations in the region around the eutectoid, using alloys of high purity, and Mehl and Wells[6] investigated metastable (iron-cementite) equilibria in the same alloys. They place the eutectoid at 0.80% carbon in the metastable system, and at 0.69% carbon in the iron-graphite system; the eutectoid temperature at 723°C. for iron-cementite, and at 738°C. for iron-graphite.

Graphite and Cementite Together—Both stable and metastable equilibria may be represented in the same alloy, as illustrated by the following example:

Well annealed malleable castings consist almost entirely of ferrite and graphite and, therefore, belong entirely to the stable system. Suppose a piece of malleable cast iron containing 2.40% graphite is heated to 1600°F. The graphite will begin to dissolve in the iron, forming austenite. This process will continue until the carbon content of the austenite reaches a value represented by a point where a 1600°F. horizontal intersects the graphite solubility curve S'E', that is, at about 1.00%. When this solution process comes to rest the alloy is in a state of equilibrium, the equilibrium belonging to the stable system. Now if the alloy is cooled slowly to room temperature, a rate of about 10-20°F. per hr. being required for

ordinary malleable, graphite will be reprecipitated. However, if the alloy is cooled moderately fast, as by air cooling, only a little graphite will be formed from the 1.00% of carbon dissolved in the austenite. Most of this carbon will precipitate as cementite, forming pearlite on passing through Ar_1. This pearlite belongs to the metastable system.

Ordinary cast irons, which generally contain both graphitic and "combined" carbon, represent a combination of stable equilibrium, attained or approached at the higher temperatures, and metastable equilibrium, produced by the more sluggish phase changes at the lower temperatures.

Remarks—Attention is called to the fact that the diagram here given represents conditions of equilibrium in iron-carbon alloys of the highest purity available to the various investigators upon whose work the diagram is based. Small amounts of impurities have appreciable effects upon temperatures at which the phase changes occur, and it has not been easy to prepare and work with iron-carbon alloys of such purity that the impurities present could be said to have no appreciable effects. Oxygen, in particular, is difficult to eliminate. Temperatures are altered, and changes represented in the diagram as occurring at constant temperature may take place over an appreciable range of temperature. In commercial steels the pearlite change at A_1, for example, takes place over a range of temperature instead of at a constant temperature, as represented in the diagram by the line PSK.

The carbon contents and temperatures which define the various points in the diagram have been selected after a review of the work of the various investigators in this field. The reader who has further interest in the subject is referred to a very thorough and critical review of the subject in the monograph on iron-carbon alloys.[14]

It will be noted that all of the lines in the diagram are drawn straight, with the exception of the line GOS. It is probable that most of these lines, with the exception of the horizontals, are curved, but it is considered that there is insufficient evidence at present on which to base the construction of lines having a definite degree of curvature. The line GOS, it seems, should be definitely curved in the direction shown and approximately to the extent shown.[6]

References

[1]A. Westgren and G. Phragmén, X-ray Studies on the Crystal Structure of Steel, J. Iron Steel Inst., 1922, v. 105, p. 241.

[2]F. Wever, Beiträge zur Kenntnis des Eisenkarbides, Mitt. Kaiser-Wilhelm Inst. Eisenforsch., 1922, v. 4, p. 67.

[3]S. Shimura, Study on Crystal Structure of Cementite, proc., World Eng. Congr., Tokyo, 1929, v. 34, p. 223.

[5]A. Westgren, Cementitens kristallstruktur (The Crystal Structure of Cementite), Jernkontorets Ann., 1932, v. 116 (87), p. 457.

[6]R. F. Mehl and C. Wells, Constitution of High Purity Iron-carbon Alloys, A.I.M.E., 1937, Tech. Pub. No. 798.

[7]W. Köster, Der Einfluss einer Wärmebehandlung unterhalb A_1 auf die Eigenschaften des technischen Eisens (The Influence of Heat Treatment Below A_1 on the Properties of Commercial Iron), Arch. Eisenhuttenw., 1929, v. 2, p. 503.

[8]H. Scott, What Is Steel?, Chem. Met. Engr., 1922, v. 27, p. 1156.

[9]J. H. Whiteley, The Solution of Cementite in Alpha Iron and Its Precipitation, J. Iron Steel Inst., 1927, v. 116, p. 293.

[10]N. B. Pilling, Micrographic Detection of Carbides in Ferrous Alloys, Trans., A.I.M.E., 1924, v. 70, p. 254.

[11]T. D. Yensen, Magnetic Properties of the Ternary Alloys Fe-Si-C, Trans., Am. Inst. Elec. Eng'rs, 1924, v. 43, p. 145. Condensed, J. Am. Inst. Elec. Eng'rs, 1924, v. 43, p. 558.

[12]C. Wells, Graphitization in High Purity Iron-Carbon Alloys, Trans., A.S.M., 1938, v. 26, p. 289.

[13]R. S. Archer, Graphitization of White Cast Iron, Trans., A.I.M.E., 1922, v. 67, p. 445.

[14]S. Epstein, Alloys of Iron & Carbon, v. 1, Constitution, McGraw-Hill Book Co., 1936.

*PHYSICAL CONSTANTS OF ELEMENTS

INTRODUCTION

The following table has been compiled from the best available sources and checked by about fifty specialists on the various elements. While the data are believed to be accurate, certain generalizations have been necessary for tabulation and should, therefore, be used only for general purposes and comparison between

Elements	Symbol	Atomic No.	Atomic Weight (1938)	Density, g./cm.^{3} at 20°C. (68°F.)	Density, lb./in.^{3} at 68°F (20°C.)	Atomic Volume, cm.^{3}/g. Atom	Melting Point, °F	Boiling Point, °F. (760 mm. Pressure)	Specific Heat, cal./g./°C. at Room Temperature Equals B.t.u./lb./°F. at Room Temperature	Latent Heat of Fusion, cal./g.	Latent Heat of Fusion, B.t.u./lb.
Actinium	Ac	89	227				3272^{d}	$>3092^{d}$			
Aluminum	Al	13	26.97	2.70	0.0975	9 99	1214.6	3733	0.2259	93	167.4
Antimony	Sb	51	121.76	6.62	0.2391	18.39	1166.9	2624	0.0493	38.26	68.87
Argon	A	18	39.944	1.6626×10^{-3}	$6{,}008 \times 10^{-5}$		−306.2	−302.4	0.1252	6.71	12.08
Arsenic	As	33	74.91	5.73	0.2070	13 07	1497^{d}	1139^{d}	0.0822		
Barium	Ba	56	137 36	3.5	0.1265	39.25	1562	2980	0.0680		
Beryllium	Be	4	9.02	1.85	0.0658	4.96	2345	5036	0.425	345.5	621.9
Bismuth	Bi	83	209.00	9.80	0.3541	21.33	519.8	2642	0.0290	12.46	22.43
Boron	B	5	10.82	2.3	0.0831	4.70	4172	4622	0.3091		
Bromine	Br	35	79.916	3.12	0.1127	25.62	19.04	137.79	0.0703	16.15	29.07
Cadmium	Cd	48	112.41	8.65	0.3125	12 99	609.6	1412 6	0.0547	13.17	23.71
Calcium	Ca	20	40 08	1.55	0.0560	25.86	1564	2709	0.157		
Carbon	C	6	12.01	2.22	0.0802	5.41		8721	0.165		
Cerium	Ce	58	140.13	6.9	0.2493	20.3	1427	2552	0.05		
Cesium	Cs	55	132.91	1.9	0.0686	69.95	78.8	1238	0.0521	3.76	6.77
Chlorine	Cl	17	35.457				−150 88	−30.28	0.226	22.97	41.35
Chromium	Cr	24	52 01	7.14	0.2579	7.29	2822	4500	0.12	31.75	57.15
Cobalt	Co	27	58.94	8.9	0.3216	6.6	2714	5252	0.0989	58.38	105.08
Columbium	Cb	41	92.91	8.57	0.3096	10.8	3542	>5972			
Copper	Cu	29	63.57	8.94	0.323	7.11	1981.4	4703	0.0918	50.6	91
Dysprosium	Dy	66	162.46								
Erbium	Er	68	167.2								
Europium	Eu	63	152.0								
Fluorine	F	9	19.00				−369.4	−304.6		10.06	18.1
Gadolinium	Gd	64	156.9								
Gallium	Ga	31	69.72	5.91	0.2135	11.8	85 6	3760	0.0788	19.16	34.5
Germanium	Ge	32	72.60	5.36	0.1937	13 54	1757.3	4892	0.0733		
Gold	Au	79	197.2	19.3	0.6973	10.22	1945.4	5371	0.0308	16.11	28.99
Hafnium	Hf	72	178.6	11.4	0.4118	15 66	3092	9740			
Helium	He	2	4.003	0.1664×10^{-3}	0.6008×10^{-5}		<-458.0	−452.0	1.25		
Holmium	Ho	67	163.5								
Hydrogen	H	1	1.0081	0.08375×10^{-3}	0.3026×10^{-5}		−434.4	−422.957	3.415	15.0	27.0
Illinium	Il	61									
Indium	In	49	114.76	7.31	0.264	15.7	322	>2642	0.0568		
Iodine	I	53	126.92	4.93	0.178	25.7	236.3	363.8	0.0523	15.76	28.40
Iridium	Ir	77	193.1	22.4	0.809	8.6	4368	8852	0.0322		
Iron	Fe	26	55.84	7 87	0.284	7.1	2795	5430	0.1075	65	117
Krypton	Kr	36	83.7	3.488×10^{-3}	3.502×10^{-3}		−275.22	−250.6			
Lanthanum	La	57	138.92	6.15	0.222	22 6	1518 8	3272	0.0446		

*Source—A.S.M. Metals Handbook, 1939 Edition.

elements. In general, the data are as published in the various sources from which they were selected.

For more complete information about the individual elements, especially regarding minor variations and effect of special treatments on the properties listed, consult the American Society of Metals Handbook.

Linear Coefficient of Thermal Expansion/°C. at Room Temperature	Linear Coefficient of Thermal Expansion/°F. at Room Temperature	Thermal Conductivity, cal./cm.²/cm./°C./sec. at Room Temperature	Electrical Resistivity, Microhm-cm.	Modulus of Elasticity (Tension), psi.	Type of Crystal Lattice	Lattice Constant (A = 10^{-8} cm.) 20°C. (68°F.)			Closest Approach of Atoms, A	Elements
						a_0	b_0	c_0		
$x10^{-6}$	$x10^{-6}$			$x10^{6}$						
										Actinium
24	13.3	0.52	2.655	10	Face-Centered Cubic	4.0413			2.858	Aluminum
11.29	6.27	0.0444	39	11.3	Rhombohedral Hexagonal	4.4974		57°6′	2.878	Antimony
		$0.406x10^{-4}$								Argon
3.86	2.14		35		Rhombohedral Hexagonal*	4.135		54°75′	2.50	Arsenic
					Body-Centered Cubic*	5.015			4.34	Barium
12.3	6.8	0.3847	18.5	42.7	Hexagonal Close Packed*	2.281		3.577	2.22	Beryllium
13.45	7.47	0.0200	115	4.6	Rhombohedral Hexagonal	4.736		57°14′	3.104	Bismuth
2	1.1		$1.8x10^{12}$		Hexagonal (?)*					Boron
										Bromine
29.8	16.6	0.217	7.59		Hexagonal Close Packed	2.9727		5.6061	2.972	Cadmium
25	13.89		4.6		Face-Centered Oubic*	5.560			3.93	Calcium
1.2	0.67	0.057	1000	0.7	Hexagonal*	2.46		6.69	1.42	Carbon
			78		Face-Centered Cubic*	5.143			3.64	Cerium
97	54		20		Body-Centered Cubic	6.2			5.3	Cesium
11.44	6.36	$0.172x10^{-4}$	$10x10^{16}$							Chlorine
8.1	4.5	0.165	13.1		Body-Centered Cubic*	2.878			2.492	Chromium
12.08	6.71	0.165	9.7		Hexagonal Close Packed*	2.507		4.072	2.50	Cobalt
7.2	4		20		Body-Centered Cubic	3.2941			2.852	Columbium
16.42	9.1	0.923	1.682	16	Face-Centered Cubic	3.6080			2.551	Copper
										Dysprosium
					Hexagonal Close Packed*	3.74		6.09	3.74	Erbium
										Europium
										Fluorine
										Gadolinium
18.3	10.2		57.1		One-Face-Centered Orthorhombic	4.506	4.506	7.642	2.447	Gallium
			$89x10^{3}$		Cubic (Diamond)	5.647			2.44	Germanium
14.4	8.0	0.7072	2.42	11.3	Face-Centered Cubic	4.0700			2.878	Gold
					Hexagonal Close Packed*	3.200		5.077	3.14	Hafnium
		$3.32x10^{-4}$								Helium
										Holmium
		$4.06x10^{-4}$								Hydrogen
										Illinium
33	18.3	0.057	9		-	4.585		4.941	3.24	Indium
93	51.7	$10.4x10^{-4}$	$1.3x10^{16}$		One-Face-Centered Orthorhombic	4.791	7.248	9.771	2.70	Iodine
6.41	3.5	0.141	6.08	$7.47x10^{7}$	Face-Centered Cubic	3.8312			2.709	Iridium
11.9	6.6	0.19	9.8	30	Body-Centered Cubic*	2.8610			2.478	Iron
		$0.212x10^{-4}$								Krypton
			59		Hexagonal Close Packed*	3.75		6.06	3.7	Lanthanum

Elements	Symbol	Atomic No.	Atomic Weight (1938)	Density, g./cm.³ at 20°C. (68°F.)	Density, lb./in.³ at 68°F. (20°C.)	Atomic Volume, cm.³/g. Atom	Melting Point, °F.	Boiling Point, °F. (760 mm. Pressure)	Specific Heat, cal./g./°C. at Room Temperature Equals B.t.u./lb./°F. at Room Temperature	Latent Heat of Fusion, cal./g.	Latent Heat of Fusion, B.t.u./lb.
Lead	Pb	82	207 21	11 34	0.409	18 3	621.2	·3171	0 030	6.26	11.27
Lithium	Li	3	6.940	0.53	0.0193	13 1	366.8	2502	0.79	32.81	59.02
Lutecium	Lu	71	175.0								
Magnesium	Mg	12	24.32	1 74	0 0628	14 0	1204	2025	0.249	70.0	126
Manganese	Mn	25	54.93	7.44	0 268	7 4	2268	3904	0.107	64.8	116.64
Masurium	Ma	43									
Mercury	Hg	80	200 61	13 55	0 489	14 8	−38.0	674 4	0.0332	2.66	4.78
Molybdenum	Mo	42	95.95	10 2	0.368	9 4	4748	8679	0.0647		
Neodymium	Nd	60	144.27	7 05	0.255	20 5	1544		0.0447		
Neon	Ne	10	20.183	0.8387×10^{-3}	3.030×10^{-5}		−415.498	−411 34			
Nickel	Ni	28	58.69	8.9	0.322	6 64	2646	5252	0.112	73 8	132.8
Nitrogen	N	7	14.008	1.1649×10^{-3}	4.209×10^{-5}		−345.87	−320.40	0.247	6.15	11.07
Osmium	Os	76	190.2	22 5	0.812	8 45	4892	9920	0.031		
Oxygen	O	8	16.0000	$1\ 3318 \times 10^{-3}$	4.8122×10^{-5}		−361.12	−297.334	0.2184	3.32	5.98
Palladium	Pd	46	106.7	12.0	0.433	8.9	2831	7196	0.0587	34.2	61.8
Phosphorus (Yellow)	P	15	31.02	1 82	0.0657	17 0	111.4	536	0.177	5.04	9.07
Platinum	Pt	78	195.23	21 45	0. 774	9 1	3224	7933	0.0319	27.1	48.78
Polonium	Po	84									
Potassium	K	19	39.096	0.86	0.031	45.5	144.1	1425	0.177	14.5	26.1
Praseodymium	Pr	59	140.92	6.63	0.239	21.3	1724		0.458		
Protoactinium	Pa	91	231								
Radium	Ra	88	226.05	5.0	0.1808	45.2	1760	2084			
Radon	Rn	86	222	4.40[c]	0.159	50.45	−95.8	−79.2			
Rhenium	Re	75	186 31	20	0.723	8.9	5432	10,600	0.0346		
Rhodium	Rh	45	102.91	12.44	0.449	8.23	3571	8132	0 0598		
Rubidium	Rb	37	85.48	1.53	0.0553	55.87	101	1292	0.0802	6.095	10.75
Ruthenium	Ru	44	101.7	12.2	0.441	8 33	4442	8852	0.061		
Samarium	Sm	62	150.43	7.7	0.28	19 4	>2400				
Scandium	Sc	21	45.10	2.5	0.09	18.0	2200	4400			
Selenium	Se	34	78.96	4.81	0.174	16 4	428	1270	0.084		
Silicon	Si	14	28.06	2.4	0.087	11.7	2600	4149	0.1762		
Silver	Ag	47	107.880	10.5	0.38	10.27	1761	3634	0.0558	24.3	43.8
Sodium	Na	11	22.997	0 97	0.035	23.7	207.5	1638	0 295	27.53	49 6
Strontium	Sr	38	87 63	2.6	0.094	33.7	1420	2523		25	45
Sulphur	S	16	32.06	2.07	0.075	15.46	235 4	832.3	0.175	9.3	16 7
Tantalum	Ta	73	180 88	16.6	0.60	10.9	5162	11,000	0.0356		
Tellurium	Te	52	127.61	6.24	0.224	20.45	846	1989	0.0468	7.305	13.15
Terbium	Tb	65	159.2				590				
Thallium	Tl	81	204 39	11 85	0 428	17 24	578	2655	0.0311	7.185	12.94
Thorium	Th	90	232.12	11.5	0.416	20 2	3353	9392	0 0276		
Thulium	Tm, Tu	69	169.4								
Tin	Sn	50	118 70	7.30	0.264	16 23	449.6	4118	0 054	14.4	25.9
Titanium	Ti	22	47.90	4.5	0 163	10 6	3272	9212	0.142		
Tungsten	W	74	183 92	19.3	0.698	9.53	6098	10,700	0.034	44	79
Uranium	U	92	238 07	18.7	0.676	12 73	3074	6332	0.0276		
Vanadium	V	23	50.95	5.68	0.205	8 97	3110	5432	0.1153		
Xenon	Xe	54	131.3	5.495×10^{-3}	$5\ 517 \times 10^{-3}$		−169.6	−160.78			
Ytterbium	Yb	70	173.04								
Yttrium	Y	39	88.92	5.51	0.199	16.13	2700	8312			
Zinc	Zn	30	65.38	7.14	0.258	9.16	787	1665	0.09	24.09	43.36
Zirconium	Zr	40	91.22	6.4	0.23	14.3	3092	9122	0.066		

[c]Liquid at −62°C.
[d]Sublimes.

[e]Single crystal, 22.4 || crystal axis
46.4 ⊥ crystal axis

[k]Single crystal, 12.4 || crystal axis
25.8 ⊥ crystal axis

Linear Coefficient of Thermal Expansion/°C. at Room Temperature	Linear Coefficient of Thermal Expansion/°F. at Room Temperature	Thermal Conductivity, cal./cm.²/cm./°C./sec. at Room Temperature	Electrical Resistivity, Microhm-cm.	Modulus of Elasticity (Tension), psi.	Type of Crystal Lattice	Lattice Constant (A = 10^{-8} cm.) 20°C. (68°F.) a₀	b₀	c₀	Closest Approach of Atoms, A	Elements
$\times 10^{-6}$	$\times 10^{-6}$			$\times 10^{-6}$						
29.5	16.4	0.083	20.65	2.56	Face-Centered Cubic	4.9389			3.492	Lead
56	31	0.17	8.5		Body-Centered Cubic	3.51			3.0	Lithium
										Lutecium
25.7	14.3	0.37	4.46	6.25	Hexagonal Close Packed	3.2022		5.1991	3.190	Magnesium
23	12.8				Cubic (Complex)*	8.894			1.065	Manganese
										Masurium
										Mercury
		0.0200	95.8							Mercury
5.49	3.05	0.350	4.77	50.2	Body-Centered Cubic	3.1403			2.720	Molybdenum
			79		Hexagonal Close Packed*	3.657		5.880	3.62	Neodymium
		1.092×10^{-4}								Neon
13.7	7.6	0.140	6.9	30	Face-Centered Cubic*	3.517			2.486	Nickel
		0.600×10^{-4}								Nitrogen
5.70	3.2		9		Hexagonal Close Packed	2.7304		4.3099	2.670	Osmium
		0.589×10^{-4}								Oxygen
11.60	6.4	0.161	10	1.70×10^{7}	Face-Centered Cubic	3.8817			2.744	Palladium
125	69		10^{17}							Phosphorus (Yellow)
8.8	4.3	0.166	9.83	2.14×10^{7}	Face-Centered Cubic	3.9158			2.768	Platinum
					Monoclinic; $\beta=92°$	7.42	4.29	14.10	2.81	Polonium
83	46	0.237	7.0		Body-Centered Cubic	5.333			4.62	Potassium
			88		Hexagonal Close Packed*	3.657		5.924	3.63	Praseodymium
										Protoactinium
										Radium
										Radon
a	b		21		Hexagonal Close Packed	2.755		4.449	2.734	Rhenium
8.9	4.5	0.213	4.93	4.25×10^{7}	Face-Centered Cubic*	3.7957			2.684	Rhodium
90.0	50.0		12.5		Body-Centered Cubic	5.7			4.9	Rubidium
8.5	4.7		10		Hexagonal Close Packed*	2.698		4.274	2.644	Ruthenium
										Samarium
										Scandium
37.0	20.6		12		Hexagonal*	4.337		4.944	2.32	Selenium
	1.6–4.1	0.20	85×10^{3}	16	Cubic (Diamond)	5.4173			2.346	Silicon
18.9	10.5	0.974	1.62	10.3	Face-Centered Cubic	4.0774			2.882	Silver
71	39.5	0.3225	4.6		Body-Centered Cubic	4.30			3.72	Sodium
			22.76		Face-Centered Cubic*	6.075			4.30	Strontium
67.48	37.49	0.00063	1.9×10^{17}		Face-Centered Orthorhombic*	10.48	12 92	24.55	2.12	Sulphur
6.5	3.6	0.130	15.5	27.0	Body-Centered Cubic	3.2959			2.854	Tantalum
16.8	9.3	0.01433			Hexagonal	4.445		5.912	2.86	Tellurium
										Terbium
28.0	15.6	0.09315	18.1		Hexagonal Close Packed*	3.450		5.520	3.40	Thallium
12.3	6.84		18		Face-Centered Cubic*	5.077			3.59	Thorium
										Thulium
e	k	0.157	11.5	5.9–7.8	Body-Centered Tetragonal*	5.819		3.175	3.016	Tin
7.14	3.96				Hexagonal Close Packed*	2.953		4.729	2.90	Titanium
4.0	2.2	0.476	5.48	60	Body-Centered Cubic*	3.1585			2.734	Tungsten
			60		Orthorhombic*	2.852	5.865	4.945	2.76	Uranium
			26		Body-Centered Cubic	3.033			2.627	Vanadium
		1.24×10^{-4}								Xenon
										Ytterbium
					Hexagonal	3.663		5.814	3.59	Yttrium
f	g	0.268	h		Hexagonal Close Packed	2.659		4.936	2.658	Zinc
6.3	3.5		41		Hexagonal Close Packed*	3.223		5.123	3.16	Zirconium

[a] 20-1917°C., 12.5 ‖ crystal axis; 4.7 ⊥ crystal axis

[b] 20-1917°C., 6.94 ‖ crystal axis; 2.61 ⊥ crystal axis

*Ordinary form at 20°C.; other modifications known or probable at other temperatures.

[f] 32.5 pure, hot rolled zinc with grain; 23.0 " " " " across rolling

[g] 18.0 pure, hot rolled zinc with grain; 12.8 " " " " across rolling

[h] Single crystal, 6.2 ‖ crystal axis; 5.8 ⊥ crystal axis

DENSITY OF ALLOYS (60°F.)

Material or Trade Designation	Approx. Composition, %	Cast sp.gr.	Cast lb./in.^{3}	Wrought sp.gr.	Wrought lb./in.^{3}
Aluminum and Aluminum Alloys					
Aluminum	Al 99.97	....	.....	2.70	0.0975
12 and 212, ASTM-B, SAE-30	Cu 8	2.82	0.102	....	.....
43, ASTM-J, SAE-35	Si 5	2.66	0.096	....	.....
47, ASTM-K, SAE-37	Si 12.5	2.63	0.095	....	.....
108	Cu 4, Si 3	2.74	0.099	....	.....
109, ASTM-E, SAE-32	Cu 12	2.91	0.105	....	.....
112, ASTM-C, SAE-33	Cu 7, Zn 2, Fe 1.2	2.85	0.103	....	.....
122T2 } 122T61 } ASTM-F, SAE-34	Cu 10, Fe 1.2, Mg 0.2	2.93	0.106	....	.....
142, ASTM-H, SAE-39	Cu 4, Ni 2, Mg 1.5	2.80	0.101	....	.....
195, ASTM-G, SAE-38	Cu 4.5	2.77	0.100	....	.....
214	Mg 3.7	2.63	0.095	....	.....
216	Mg 6	2.60	0.094	....	.....
220	Mg 10	2.55	0.092	....	.....
A 334	Cu 3, Si 4, Mg 0.3	2.74	0.099	....	.....
355	Cu 2, Si 5, Mg 0.5	2.69	0.097	....	.....
A 355	Cu 1.4, Si 5, Mn 0.7, Ni 0.7, Mg 0.5	2.74	0.099	....	.....
356	Si 7, Mg 0.3	2.63	0.095	....	.....
645	Zn 11, Cu 2.5, Fe 1.5	2.93	0.106	....	.....
A 108	Cu 4.5, Si 5.5	2.74	0.099	....	.....
B 113	Cu 7, Si 1.5, Fe 1.2	2.88	0.104	....	.....
132	Si 14, Cu 1, Fe 1, Mg 1, Ni 2	2.71	0.098	....	.....
144	Cu 10, Si 4, Mg 0.25	2.88	0.104	....	.....
B 195	Cu 4.5, Si 3	2.77	0.100	....	.....
D 195	Cu 5.5	2.82	0.102	....	.....
A 214	Mg 3.75, Zn 2	2.66	0.096	....	.....
2S	Commercial Al	....	.....	2.71	0.098
3S	Mn 1.25	....	.....	2.73	0.099
4S	Mn 1.25, Mg 1	....	.....	2.72	0.098
17S (Duralumin)	Cu 4, Mn 0.5, Mg 0.5	....	.....	2.79	0.101
24S	Cu 4.2, Mn 0.6, Mg 1.5	....	.....	2.76	0.100
25S	Cu 4.5, Si 0.8, Mn 0.8	....	.....	2.79	0.101
51S	Si 1, Mg 0.6	....	.....	2.69	0.097
52S	Mg 2.5, Cr 0.25	....	.....	2.67	0.096
53S	Si 0.7, Mg 1.25, Cr 0.25	....	.....	2.69	0.097
Copper and Copper Alloys					
Copper (electrolytic)	99.90 +	....	.....	8.89	0.3217
(deoxidized)	99.90 +	....	.....	8.93	0.323
Primer Gilding	Cu 97, Zn 3	....	.....	8.89	0.321
Gilding	Cu 95, Zn 5	....	.....	8.866	0.320
Commercial Bronze	Cu 90, Zn 10	....	.....	8.804	0.318
Red Brass 85%	Cu 85, Zn 15	....	.....	8.745	0.316
Red Brass 80%	Cu 80, Zn 20	....	.....	8.667	0.313
Brazing Brass	Cu 75, Zn 25	....	.....	8.594	0.310
Spring Brass	Cu 72, Zn 28	....	.....	8.553	0.309
Cartridge Brass	Cu 70, Zn 30	....	.....	8.528	0.308
Eyelet Brass	Cu 68, Zn 32	....	.....	8.50	0.307
Commercial High Brass	Cu 65, Zn 35	....	.....	8.47	0.306
Brass Wire	Cu 63, Zn 37	....	.....	8.437	0.305
Muntz Metal	Cu 60, Zn 40	....	.....	8.396	0.303
Tube Brass	Cu 67.5, Zn 32, Pb 0.5	....	.....	8.495	0.307
Leaded Comm. Bronze	Cu 88.5, Zn 10, Pb 1.5	....	.....	8.83	0.319
Leaded Red Brass 80%	Cu 78.5, Zn 20, Pb 1.5	....	.....	8.698	0.314
Leaded Brass	Cu 69, Zn 29.5, Pb 1.5	....	.....	8.562	0.309
Forging Brass	Cu 60, Zn 38, Pb 2	....	.....	8.44	0.305
Free Cutting Rod	Cu 62, Zn 35, Pb 3	....	.....	8.489	0.307
Naval Brass or Tobin Bronze	Cu 60, Zn 39.25, Sn 0.75	....	.....	8.404	0.304
Fourdrinier Wire	Cu 81, Zn 18.75, Sn 0.25	....	.....	8.712	0.315
Special Bronze	Cu 98.75, Sn 1.25	....	.....	8.89	0.321
Signal Bronze	Cu 98.25, Sn 1.75	....	.....	8.89	0.321
Phosphor Bronze	Cu 96, Sn 3.75, P 0.25	....	.....	8.88	0.320
Chain Bronze	Cu 95, Sn 5	....	.....	8.87	0.320
Leaded Chain Bronze	Cu 94, Pb 1, Sn 5	....	.....	8.929	0.322
Gun Metal	Cu 92, Sn 8	....	.....	8.815	0.318
Coe Bronze	Cu 89.5, Sn 10.5	....	.....	8.78	0.317
Free Cutting Phos. Bronze	Cu 88, Zn 4, Pb 4, Sn 4	....	.....	8.86	0.320
Super Nickel	Cu 70, Ni 30	....	.....	8.95	0.323
15% Cupro Nickel	Cu 85, Ni 15	....	.....	8.95	0.323
Constantan	Cu 55, Ni 45	....	.....	8.90	0.322
30% Nickel Silver	Cu 47, Zn 23, Ni 30	....	.....	8.74	0.316
Ambrac B	Cu 65, Zn 5, Ni 30	....	.....	8.86	0.320
Ambrac A	Cu 75, Zn 5, Ni 20	....	.....	8.86	0.320
25% Nickel Silver	Cu 55, Zn 20, Ni 25	....	.....	8.72	0.315
18% Nickel Silver	Cu 65, Zn 17, Ni 18	....	.....	8.752	0.316
18% Nickel Silver	Cu 55, Zn 27, Ni 18	....	.....	8.68	0.314
15% Nickel Silver	Cu 64, Zn 21, Ni 15	....	.....	8.691	0.314
15% Nickel Silver	Cu 57, Zn 28, Ni 15	....	.....	8.631	0.312
10% Nickel Silver	Cu 65, Zn 25, Ni 10	....	.....	8.675	0.313
5% Aluminum Bronze	Cu 95, Al 5	....	.....	8.176	0.295
8% Aluminum Bronze	Cu 92, Al 8	....	.....	7.80	0.281
8% Al Bronze with Fe	Cu 89.5, Al 8, Fe 2.5	....	.....	7.74	0.280
10% Al Bronze	Cu 90, Al 10	....	.....	7.57	0.273
Avialite	Cu 90, Al 9.50, Fe 0.5	....	.....	7.585	0.274

Linear Coefficient of Thermal Expansion/°C. at Room Temperature	Linear Coefficient of Thermal Expansion/°F. at Room Temperature	Thermal Conductivity, cal./cm.²/cm./°C./sec. at Room Temperature	Electrical Resistivity, Microhm-cm.	Modulus of Elasticity (Tension), psi.	Type of Crystal Lattice	Lattice Constant (A = 10^{-8} cm.) 20°C. (68°F.)			Closest Approach of Atoms, A	Elements
						a_o	b_o	c_o		
$\times10^{-6}$	$\times10^{-6}$			$\times10^{-6}$						
29.5	16.4	0.083	20.65	2.56	Face-Centered Cubic	4.9389			3.492	Lead
56	31	0.17	8.5		Body-Centered Cubic	3.51			3.0	Lithium
										Lutecium
25.7	14.3	0.37	4.46	6.25	Hexagonal Close Packed	3.2022		5.1991	3.190	Magnesium
23	12.8				Cubic (Complex)*	8.894			1.065	Manganese
										Masurium
		0.0200	95.8							Mercury
5.49	3.05	0.350	4.77	50.2	Body-Centered Cubic	3.1403			2.720	Molybdenum
			79		Hexagonal Close Packed*	3.657		5.880	3.62	Neodymium
		1.092×10^{-4}								Neon
13.7	7.6	0.140	6.9	30	Face-Centered Cubic*	3.517			2.486	Nickel
		0.600×10^{-4}								Nitrogen
5.70	3.2		9		Hexagonal Close Packed	2.7304		4.3099	2.670	Osmium
		0.589×10^{-4}								Oxygen
11.60	6.4	0.161	10	1.70×10^{7}	Face-Centered Cubic	3.8817			2.744	Palladium
125	69		10^{17}							Phosphorus (Yellow)
8.8	4.3	0.166	9.83	2.14×10^{7}	Face-Centered Cubic	3.9158			2.768	Platinum
					Monoclinic; $\beta=92°$	7.42	4.29	14.10	2.81	Polonium
83	46	0.237	7.0		Body-Centered Cubic	5.333			4.62	Potassium
			88		Hexagonal Close Packed*	3.657		5.924	3.63	Praseodymium
										Protoactinium
										Radium
										Radon
a	b		21		Hexagonal Close Packed	2.755		4.449	2.734	Rhenium
8.9	4.5	0.213	4.93	4.25×10^{7}	Face-Centered Cubic*	3.7957			2.684	Rhodium
90.0	50.0		12.5		Body-Centered Cubic	5.7			4.9	Rubidium
8.5	4.7		10		Hexagonal Close Packed*	2.698		4.274	2.644	Ruthenium
										Samarium
										Scandium
37.0	20.6		12		Hexagonal*	4.337		4.944	2.32	Selenium
	1.6–4.1	0.20	85×10^{3}	16	Cubic (Diamond)	5.4173			2.346	Silicon
18.9	10.5	0.974	1.62	10.3	Face-Centered Cubic	4.0774			2.882	Silver
71	39.5	0.3225	4.6		Body-Centered Cubic	4.30			3.72	Sodium
			22.76		Face-Centered Cubic*	6.075			4.30	Strontium
67.48	37.49	0.00063	1.9×10^{17}		Face-Centered Orthorhombic*	10.48	12 92	24.55	2.12	Sulphur
6.5	3.6	0.130	15.5	27.0	Body-Centered Cubic	3.2959			2.854	Tantalum
16.8	9.3	0.01433			Hexagonal	4.445		5.912	2.86	Tellurium
										Terbium
28.0	15.6	0.09315	18.1		Hexagonal Close Packed*	3.450		5.520	3.40	Thallium
12.3	6.84		18		Face-Centered Cubic*	5.077			3.59	Thorium
										Thulium
e	k	0.157	11.5	5.9–7.8	Body-Centered Tetragonal*	5.819		3.175	3.016	Tin
7.14	3.96				Hexagonal Close Packed*	2.953		4.729	2.90	Titanium
4.0	2.2	0.476	5.48	60	Body-Centered Cubic*	3.1585			2.734	Tungsten
			60		Orthorhombic*	2.852	5.865	4.945	2.76	Uranium
			26		Body-Centered Cubic	3.033			2.627	Vanadium
		1.24×10^{-4}								Xenon
										Ytterbium
					Hexagonal	3.663		5.814	3.59	Yttrium
f	g	0.268	h		Hexagonal Close Packed	2.659		4.936	2.658	Zinc
6.3	3.5		41		Hexagonal Close Packed*	3.223		5.123	3.16	Zirconium

[a] 20-1917°C., 12.5 || crystal axis
4.7 ⊥ crystal axis

[b] 20-1917°C., 6.94 || crystal axis
2.61 ⊥ crystal axis

*Ordinary form at 20°C.; other modifications known or probable at other temperatures.

[f] 32.5 pure, hot rolled zinc with grain
23.0 " " " " across rolling

[g] 18.0 pure, hot rolled zinc with grain
12.8 " " " " across rolling

[h] Single crystal, 6.2 || crystal axis
5.8 ⊥ crystal axis

DENSITY OF ALLOYS—Continued

Material or Trade Designation	Approx. Composition, %	Cast sp.gr.	Cast lb./in.^{3}	Wrought sp.gr.	Wrought lb./in.^{3}
Calsun Bronze	Cu 95.5, Al 2.5, Sn 2.0	....	.....	8.540	0.308
Manganese Bronze	Cu 59, Zn 39, Mn 0.5, Fe 0.80, Sn 0.70	....	.....	8.370	0.302
Everdur 1010	Cu 96, Mn 1, Si 3	....	.....	8.539	0.308
Everdur 1015	Cu 98.25, Mn 0.25, Si 1.5	....	.....	8.740	0.316
Hitenso A	Cu 99.35, Cd 0.65	....	.....	8.89	0.321
Hitenso BB	Cu 99, Cd 1	....	.....	8.89	0.321
Hitenso C	Cu 98.6, Cd 0.8, Sn 0.6	....	.....	8.89	0.321
Tempaloy 917	Cu 81.9, Fe 2.5, Ni 5, Al 9.6, Mn 1	....	.....	7.569	0.273
Architectural Bronze	Cu 57, Zn 40, Pb 2.5, Sn 0.34, Fe 0.16	....	.....	8.432	0.305
Beryllium Copper	Cu 97.75, Be 2.25	....	.....	8.23	0.297
Bronze A	Cu 87, Al 9.8, Fe 3.2	....	.....	7.71	0.279
Bronze B	Cu 85.6, Al 10.8, Fe 3.6	....	.....	7.58	0.274
Die Casting Alloys					
ASTM-XXI, SAE-921	Zn 92.8, Cu 3, Al 4, Mg 0.1, Fe 0.1	6.7	0.242	....	.....
ASTM-XXIII, SAE-903	Zn 95.75, Cu 0.1, Al 4, Mg 0.05, Fe 0.1	6.64	0.240	....	.....
Bearing Metals					
ASTM-1	Cu 4.5, Sn 91, Sb 4.5	7.34	0.265	....	.....
ASTM-2	Cu 3.5, Sn 89, Sb 7.5	7.39	0.267	....	.....
ASTM-3	Cu 8⅓, Sn 83⅓, Sb 8⅓	7.46	0.269	....	.....
ASTM-4	Cu 3, Sn 75, Sb 12, Pb 10	7.52	0.272	....	.....
ASTM-5	Cu 2, Sn 65, Sb 15, Pb 18	7.75	0.280	....	.....
ASTM-6	Cu 1.5, Sn 20, Sb 15, Pb 63.5	9.33	0.337	....	.....
ASTM-7	Sn 10, Sb 15, Pb 75	9.73	0.352	....	.....
ASTM-8	Sn 5, Sb 15, Pb 80	10.04	0.363	....	.....
ASTM-9	Sn 5, Sb 10, Pb 85	10.24	0.370	....	.....
ASTM-10	Sn 2, Sb 15, Pb 83	10.07	0.364	....	.....
ASTM-11	Sb 15, Pb 85	10.28	0.371	....	.....
ASTM-12	Sb 10, Pb 90	10.67	0.386	....	.....
SAE 65 (T-1)	Cu 88.75, Sn 11, Pb 0.25	8.5	0.307	....	.....
SAE 63 (T-2)	Cu 87.5, Sn 11, Pb 1.5	8.8	0.316	....	.....
T-3	Cu 85, Sn 10, Pb 5	8.7	0.314	....	.....
T-4	Cu 84, Sn 10, Pb 2.5, Ni 3.5	8.8	0.318	....	.....
T-5	Cu 84, Sn 16	8.6	0.310	....	.....
T-6	Cu 80, Sn 20	8.7	0.314	....	.....
T-7	Cu 80, Sn 10, Pb 10	8.9	0.322	....	.....
T-8	Cu 78, Sn 8, Pb 14	9.4	0.339	....	.....
T-9	Cu 70, Sn 9, Pb 21	9.5	0.346	....	.....
T-10	Cu 70, Sn 4, Pb 26	9.7	0.376	....	.....
T-11	Cu 10, Al 4, Zn 86	6.9	0.250	....	.....
Illium	Ni Cr Cu	...	.....	8.3	0.3
Ferrous Metals					
Iron	99.97 Fe	....	.....	7.87	0.284
Armco Iron	< 0.1 Total of C, Mn, S, P, S Si	....	.....	7.86	0.284
Soft Steel	C 0.10	....	.....	7.85	0.284
Structural Steel	C 0.25	....	.....	7.85	0.284
Carbon Steel	C 0.40	....	.....	7.84	0.283
Spring Steel	C 0.75	....	.....	7.83	0.283
Tool Steel	C 0.90	....	.....	7.82	0.283
Malleable Cast Iron	C 2.50	7.42	0.268	.....	....
Gray Cast Iron	C 3.50	7.0–7.22	0.253–0.261	.....	....
Strong Gray Cast Iron	C 3.50	7.22	0.261	.....	....
High Strength Cast Iron	C 3.00	7.30	0.264	.....	....
Alloy Cast Iron	C 2.75	7.35	0.266	.....	....
Wrought Iron		....	.....	7.4–7.9	0.267–0.285
Stainless Steel	Cr 18-20, Ni 8-10,	....	.....	7.92	0.286
Stainless Steel	Cr 22-26, Ni 11-13, C 0.20	....	.....	7.84	0.283
Stainless Steel	Cr 16-18, C 0.12	....	.....	7.56	0.273
Stainless Steel	Cr 23-30, C 0.35	....	.....	7.48	0.270
Duriron	Si 14.5, Mn 0.35, C 0.80, Fe Bal.	7.0	0.253	....	.....
Silicon Steel (Magnetic)	Si 0.60	....	.....	7.5	0.271
Silicon Steel (Magnetic)	Si 1.00	....	.....	7.5	0.271
Silicon Steel (Magnetic)	Si 1.17	....	.....	7.7	0.278
Silicon Steel (Magnetic)	Si 1.30	....	.....	7.7	0.278
Magnesium Alloys					
Magnesium	....	....	.....	1.74	0.063
ASTM-1 Dow-A	Al 8, Mn 0.2, Mg 91.8	1.80	0.065	....	.....
ASTM-2 Dow-G	Al 10, Mn 0.1, Mg 89.9	1.81	0.066	....	.....
ASTM-3 Dow-B	Al 12, Mn 0.1, Mg 87.9	1.82	0.066	....	.....
ASTM-4 Dow-H	Al 6, Mn 0.2, Zn 3, Mg 90.8	1.84	0.066	....	.....
ASTM-6 Dow-F	Al 4, Mn 0.3, Mg 95.7	....	.....	1.77	0.064
ASTM-8 Dow-J	Al 6.5, Mn 0.3, Zn 0.75, Mg 92.45	....	.....	1.81	0.065

DENSITY OF ALLOYS—Continued

ASTM-9	Al 8.5, Mn 0.2, Zn 0.5, Mg 90.8	....	.....	1.83	0.066
ASTM-10	Mn 1.0, Sn 6.0, Mg 93	...	.....	1.85	0.067
ASTM-11 Dow-M	Mn 1.5, Mg 98.5	....	.....	1.76	0.064
ASTM-14	Al 10, Mn 0.1, Zn 1.0, Mg 88.9	1.82	0.06575	....	.....
Nickel and Nickel Alloys					
Nickel		....	.....	8.85	0.320
Copper-Nickel	Ni 20, Cu 80	....	.....	8.96	0.324
Copper-Nickel	Ni 30, Cu 70	....	.....	8.93	0.323
Copper-Nickel	Ni 45, Cu 55	....	.....	8.90	0.322
Copper-Nickel	Ni 70, Cu 30	....	.....	8.80	0.318
Monel	Ni 65-70, Cu 26-30, Fe 3, Mn 1.5, Si 0.25, C 0.25	....	.....	8.80	0.318
Permalloy	Ni 78	....	.....	8.6	0.311
Hypernik	Ni 50	....	.....	8.3	0.300

Source—A.S.M. Metals Handbook, 1939 Edition.

HEAT CONTENTS ABOVE 0° C.

	°C. 100 °F. 212	200 392	300 572	400 752	600 1112	800 1472	1000 1832	1200 2192	1500 2732
	Calories Per Gram†								
Aluminum	21.2	43.8	67.9	93.8	148S	296L	348	...	...
Antimony	5.0	10.1	15.4	20.9	32.3S	83.2L	95	...	...
Arsenic	8.0	16.3	24.8	33.5	52.2	73.6	...	...	...
Beryllium	43.8	94.8	152	212	339	474	...	...	...
Bismuth	2.98	6.07S	21.4L	25.1	32.3	39.6	46.8	...	...
Boron	25.2	56.7	94.4	136.8	230	333	...	...	...
Cadmium	5.6	11.3	17.4S	36.6L	49.3	62	...	...	...
Calcium	15.9	32.2	50.3	68.9α 71.7β	108.5	149	...	...	...
Carbon	20.7	45.4	74.3	108.2	183.5	269	357	448	590
Chromium	11.1	23	35.1	47.6	73.8	103	135	170	229
Cobalt	10.5	21.6	33.1	45.5	71.6	99.5	131	163.5S	279L
Copper	9.3	18.8	28.7	38.6	59.3	81	103S	175.5L	211
Germanium	7.4	15.1	23.1	30	...	...	...	...	...
Gold	3.05	6.2	9.4	12.75	19.7	26.7	34S	56.8L	67.4
Iron	10.9	22.7	36	50.7	83.6α	126β	165.5γ	196γ	247
Iridium	3.1	6.3	9.55	12.8	19.8	26.9	34.5	42.2	54.5
Lead	3.1	6.3	9.6S	18.8L	25.4	32	38.6	...	...
Lithium	91	...	...	...	...	...	...	...	...
Magnesium	24.6	50.6	77.8	106	165S	267L	...	...	...
Manganese	11.2	23.7	37.3	52.8	87.8	128α	166β	207γ	330L
Molybdenum	6.05	12.5	19.3	26.3	41	56.5	72.5	89.9	117
Nickel	10.9	22.7	35.7α	50.7β	77	103.8	131	159β	274L
Osmium	3.1	6.3	9.5	12.8	19.5	26.3	33.5	40.7	...
Palladium	5.6	11.3	17.2	23.7	36.6	50.4	64.5	79.5	102.8
Platinum	3.2	6.5	9.8	13.1	20.2	27.4	34.9	42.7	54.6
Rubidium	6.0	12.1	18.4	24.9	38.9	53.7	69.1	85.2	110.5
Ruthenium	6.7	13.6	20.6	27.8	42.8	58.7	75.3α	92.6 β γ	119δ
Selenium	7.9	16.7S	33.5L	...	...	...	...	...	...
Silicon	17.6	36.6	57.2	78.0	121	165	...	...	...
Silver	5.6	11.3	17.2	23.3	35.9	49S	88L	103	...
Tantalum	3.4	6.9	10.5	14.1	21.5	29.1	...	...	...
Tellurium	4.7	9.6	14.8	20.0	...	...	...	...	...
Thallium	3.2	6.6α	11.0β	18.2L	25.1	...	...	...	...
Tin	5.6	11.6S	31.8L	37.4	48.5	59.7	70.8	...	...
Titanium	11.3	25.3	44.5	63.7	...	...	...	...	...
Tungsten	3.3	6.5	9.9	13.2	20.1	27.1	34.4	41.8	53.5
Zinc	9.4	19.1	29.4	40.0S	88.5L	114	...	...	...

S = Solid. L = Liquid.
†Multiply by 1.8 to convert to B.t.u. per lb.

Source—A.S.M. Metals Handbook, 1939 Edition.

WEIGHTS AND SPECIFIC GRAVITIES

DENSITY TABLES

The specific gravities of solids and liquids refer to water at 4°C, those of gases, when in ( ), to air at 0°C and 760 mm. pressure. Weight of water at 4°C = 62.4283 lbs. per cubic foot.

		Lbs. Per Cu. Ft.	Specific Gravity
Acid, Acetic 90%	At $\frac{20^\circ}{4^\circ}$ C	66.55	1.066
Acid, Hydrofluoric 50%	At $\frac{20^\circ}{4^\circ}$ C	74.79	1.198
Acid, Muriatic (Hydrochloric) 40%	At $\frac{20^\circ}{4^\circ}$ C	74.91	1.201
Acid, Nitric 35%	At $\frac{20^\circ}{4^\circ}$ C	76.10	1.219
Acid, Nitric 91%		93.32	1.495
Acid, Phosphoric 75%		98.57	1.579
Acid, Sulfuric 87%		112.07	1.795
Acid, Sulfuric 97%		114.65	1.836
Air 0°C and 760 mm		0.08072	(1.0)
Alcohol, Ethyl (Grain) 100%	At 20°C	49.4	0.791
Alcohol, Methyl (Wood) 100%	At 0°C	50.5	0.810
Alum (Potassium Aluminum Sulfate)		109.25	1.75
Aluminum, Hard drawn	At 20°C	168.5	2.699
Aluminum, Liquid	At 659°C	148.7	2.382
Aluminum, Alloys		......	.....
99.2 Al (Aluminum 2 S)		169.19	2.71
90 Al, 10 Mg (Magnalium)		156.08	2.50
70 Al, 30 Mg (Magnalium)		124.86	2.00
98 Al, 1.25 Mn (Aluminum alloy 3 S)		171.06	2.74
95 Al, 5 Si (Aluminum-Silicon 43)		166.06	2.66
91 Al, 9 Zn		174.80	2.80
Ammonia, Liquid 30%		55.69	0.8920
Ammonia, Gas		0.0481	(0.592)
Antimony, Vacuo-distilled	At 20°C	413.1	6.618
Arsenic, Metallic	At 15°C	357.7	5.73
Asbestos (Rock)		125–175	2.0–2.8
Asbestos, slate		112	1.8
Ash, Cinders		40–45	0.64–0.72
Asphalt		69–94	1.1–1.5
Babbitt		454	7.27
Barium		236.0	3.78
Basalt		150–190	2.4–3.1
Bauxite (Hydrated Alumina)		159.20	2.55
Beryllium		115.50	1.85
Bismuth, Electrolytic		608.5	9.747
Bismuth Alloys		.....	.....
50 Bi, 25 Pb, 12.5 Sn, 12.5 Cd (Wood's Metal)		659.23	10.56
53 Bi, 32 Pb, 15. Sn (Eutectic Fusible Alloy)		659.23	10.56
Bluestone (Copper Sulfate)		224.94	3.603
Borax (Sodium Tetraborate)		108.0	1.73
Boron, Crystal		158.3	2.535
Brass (See Copper Alloys)		.....	.....
Brick, Best Pressed		137.3–143.6	2.2–2.3
Brick, Common and Hard		112.4–124.9	1.8–2.0
Brick, Soft		93.6–106.1	1.5–1.7
Bromine, Liquid		194.8	3.12
Bronze (See Copper Alloys)		.....	.....

DENSITY TABLES—Continued

		Lbs. Per Cu. Ft.	Specific Gravity
Cadmium, Cast	At 20°C	539.9	8.648
Cadmium, Liquid	At 318°C	498.8	7.99
Calcite (Mineral Calcium Carbonate)		169.25	2.711
Calcium		96.1	1.54
Carbon		140.5	2.25
Carbon Dioxide		.1234	(1.5291)
Carbon Monoxide		.0781	(0.9673)
Caustic Soda (Sodium Hydroxide)		132.98	2.13
Cement, Portland, Loose		90	1.44
Cement, Portland, set		168.6–199.8	2.7–3.2
Cement Mortar, set		87.4–118.6	1.4–1.9
Cerium, Electrolytic		423.9	6.79
Cerium, Pure		430.7	6.9
Chalk (Calcium Carbonate)		118–175	1.9–2.8
Charcoal, Pine		18–28	0.28–0.44
Charcoal, Oak		35	0.57
Charcoal, Coal		10–14	0.16–0.22
Chromium, Pure	At 20°C	432.0	6.92
Cinders (Coal Ashes and Clinkers)		40–45	0.64–0.72
Cinnabar (Mercuric Sulfide)		507	8.12
Clay, Dry, Loose		63	1.0
Clay, Dry, Packed		95	1.52
Clay, Potters, Dry		112–162	1.8–2.6
Clay, Excavated, Damp and Plastic		110	1.76
Clay, Excavated and Gravel, Dry		100	1.6
Clay, Excavated in Water		80	1.28
Coal, Anthracite		87–112	1.4–1.8
Coal, Anthracite, Piled		47–58	0.75–0.93
Coal, Bituminous		75–94	1.2–1.5
Coal, Bituminous, Piled		40–54	0.64–0.86
Cobalt	At 21°C	543.7	8.71
Coke		62–105	1.0–1.7
Coke, Loose, Good Quality		23–32	0.14–0.51
Columbium	At 15°C	524.4	8.4
Concrete, Cement, Stone, Sand		137.3–149.8	2.2–2.4
Copper		556.79	8.92
Copper, Cast		518.1–558.7	8.30–8.95
Copper, Annealed	At 20°C	555.0	8.89
Copper, Hard Drawn	At 20°C	555.0	8.89
Copper, Liquid		513.0	8.217
Copper, Wrought		552.5–558.7	8.85–8.95
Copper, Alloys		......	......
85 Cu, 15 Zn (Red Brass)		546.26	8.75
70 Cu, 29 Zn, 1 Sn (Admiralty)		510.05	8.17
67 Cu, 33 Zn (Ordinary Yellow Brass)		524.41	8.40
61 Cu, 39 Zn (Pin Wire Brass)		524.41	8.40
60 Cu, 40 Zn (Muntz Metal)		524.41	8.40
59 Cu, 30 Zn, 11 Ni (German Silver)		520.64	8.34
52 Cu, 26 Zn, 22 Ni (German Silver)		527.53	8.45
90 Cu, 10 Al (Aluminum Bronze)		474.47	7.6
95 Cu, 5 Mn (Manganese Bronze)		549.39	8.8
82 Cu, 15 Mn, 3 Ni (Manganin)		530.66	8.5

		Lbs. Per Cu. Ft.	Specific Gravity
65 Cu, 18 Ni, 17 Zn (Nickel Silver 18% A)		546.26	8.75
60 Cu, 40 Ni (Constantin)		554.35	8.88
55 Cu, 18 Ni, 27 Zn (Nickel Silver 18% B)		542.52	8.69
95.5 Cu, 4.3 Sn, 0.2 P (Phosphor Bronze 30)		556.25	8.91
92 Cu, 8 Sn (Bronze, Gun Metal)		549.38	8.8
67 Cu, 33 Sn (Bronze, Speculum Metal)		536.90	8.6
Cork, Dry		14–16	0.22–0.26
Corundum, Pure		245–250	3.9–4.0
Dolomite		177	2.84
Duralumin (See Aluminum Alloys)		174.2	2.79
Earth, Dry, Loose		76	1.21
Earth, Dry, Packed		95	1.52
Ebonite		72	1.15
Emery		250	4.0
Erbium		298.0	4.77
Feldspar, Orthaclase		159–172	2.55–2.75
Flint		164	2.63
Gallium	At 25°C	369.1	5.903
Gas, Illuminating		.028–.036	(0.35–0.45)
Gas, Natural		.038–.039	(0.47–0.48)
Gasoline, Motor		41.0–43.0	0.66–0.69
Germanium	At 20°C	340.9	5.46
German Silver (See Copper Alloys)		......	......
Glass, Common Window		150–175	2.4–2.8
Glass, Crown or Plate		156.1–181	2.5–2.9
Glass, Crystal		181–187.3	2.9–3.0
Glass, Flint		180–370	2.9–5.9
Gneiss, Serpentine		156.1–165.4	2.50–2.65
Gold, Cast, Pure or 24-Carat		1204.8	19.3
Gold, Pure, Cold Rolled	At 20°C	1204.6	19.296
Gold Alloys		......	......
42 Au, 38-46 Cu, 12-20 Ag (Gold 10 carat)			
60 Au, 40 Pt (Platinum, gold, white)			
91.66 Au, 4.16 Ag, 4.16 Cu (Gold 22 carat)			
63 Au, 23 Ag, 15 Cu (Gold Solder)			
Granite, Syenite		165–172	2.64–2.76
Graphite		144–170	2.30–2.72
Gravel, Sand, Dry, Loose	Car.	90–105	1.4–1.7
Gun Metal (See Copper Alloys)		549.38	8.8
Gypsum, Plaster of Paris Rock, No Surface Water		144–145	2.31–2.33
Hornblende		187	3.0
Hydrogen, Liquid	At —252°C	4.4	0.07
Ice (See Water)		57.2	0.917
Indium		454.5	7.28
Iodine, Solid	At 20°C	308.4	4.94
Iridium	At 17°C	1399.6	22.42
Iron, Cast, White		473.2–482.6	7.58–7.73
Iron, Cast, Gray		438.9–445.1	7.03–7.13
Iron, Pure		490.1–491.9	7.85–7.88
Iron, White Cast		473.2–482.6	7.58–7.73
Iron, Wrought		486.9–493.2	7.80–7.90
Iron, Cast, Pig		450	7.2

		Lbs. Per Cu. Ft.	Specific Gravity
Iron, Steel		474.4–486.9	7.60–7.80
Iron, Spiegeleisen		468.2	7.5
Iron, Ferro-silicon		418.3–455.7	6.7–7.3
Iron Ore, Hematite		306–330	4.9–5.3
Iron Ore, Limonite		224.7–249.7	3.6–4.0
Iron Ore, Magnetite		306–324	4.9–5.2
Iron Slag		156–187.3	2.5–3.0
Kerosene		51.2	0.82
Lead, Cast	At 20°C	708.4	11.347
Lead, Molten	At 325°C	664.5	10.645
Lead Alloys		......	......
99.8 Pb, 0.2 As (Lead Shot)		708	11.34
94 Pb, 6 Sb (Battery Plates)		686	11.0
82 Pb, 15 Sb, 3 Sn (Type Metal)		596	9.55
75 Pb, 19 Sb, 5 Sn, 1 Cu (White Metal)		593.09	9.5
70 Pb, 18 Sb, 10 Sn, 2 Cu (Type Metal)			
99.93 Pb, 0.08 Cu (Chemical Lead)		708.58	11.35
67 Pb, 33 Sn (Solder, Plumber's)		586.84	9.4
58 Pb, 26 Sn, 15 Sb, 1 Cu (Type Metal, Standard)			
50 Pb, 50 Sn (Solder, half and half)		554.69	8.88
Lignite		68–87	1.1–1.4
Lime, Slaked		81–87	1.3–1.4
Limestone and Marble		167–171	2.68–2.76
Lithium	At 20°C	33.3	0.534
Lye (Caustic Soda)		132.98	2.13
Magnetite (See Iron Ore)		306–324	4.9–5.2
Magnesium		108.7	1.741
Manganese		463.2	7.42
Manganese Ore, Pyrolusite		295.3–303.4	4.73–4.86
Manganin (See Copper Alloys)		......	......
Marble		160–177	2.6–2.84
Mercury	At 0°C	848.8	13.596
Mica		165–200	2.6–3.2
Molybdenum		636.8	10.2
Monel Metal (See Nickel Alloys)		555.63	8.90
Mortar (See Cement)		......	......
Mud, River		90	1.44
Nickel, Cast		536.9–555.6	8.60–8.90
Nickel Alloys		......	......
80 Ni, 20 Cr. (Nichrome IV)		530.66	8.50
60 Ni, 33 Cu, 6.5 Fe (Monel Metal)		555.63	8.90
61 Ni, 23 Fe, 16 Cr (Chromel C)		514.42	8.24
60 Ni, 24 Fe, 16 Cr, 0.1 C (Nichrome)		510.05	8.17
Nitrogen, Liquid	At —195°C	50.6	0.81
Oil, Cotton Seed	At 16°C	57.8	0.926
Oil, Lard	At 15°C	57–57.1	0.913–0.915
Oil, Linseed, Boiled	At 15°C	58.8	0.942
Oil, Mineral Lubricating		56.2–58.1	0.90–0.93
Oil, Sperm	At 15°C	54.8–55.2	0.878–0.884
Oil, Olive	At 15°C	57.3	0.918
Oil, Tung		58.6–59.2	0.939–0.949
Oil, Whale		57.2–57.7	0.917–0.924

DENSITY TABLES—Continued

		Lbs. Per Cu. Ft.	Specific Gravity
Osmium		1404.6	22.5
Oxygen, Liquid	At —184°C	71.2	1.14
Palladium		759.1	12.16
Paper		44–72	0.7–1.15
Paraffine		54–57	0.87–0.91
Peat, Blocks		52	0.84
Petroleum, Crude		55	0.88
Petroleum, Refined		49.3–51.2	0.79–0.82
Petroleum, Benzine	At 0°C	56.1	0.899
Petroleum, Gasoline		41–43	0.66–0.69
Phosphate Rock, Apatite		196.7–204.1	3.151–3.270
Phosphorus, Red		137.3	2.20
Phosphorus, White or Yellow		114.2	1.83
Pitch		67	1.07
Plaster		143	2.3
Platinum	At 20°C	1334.1	21.37
Porcelain		143–156	2.3–2.5
Porphyry		162–181	2.6–2.9
Potassium	At 20°C	54.3	0.87
Pumice, Natural		23.1–56.2	0.37–0.90
Quartz		161.7–166.1	2.59–2.66
Rhodium		776.6	12.44
Rosin		67	1.07
Rubber, Caoutchouc		57–62	0.92–0.99
Rubber, Hard		74	1.19
Rubber, Soft Commercial		69	1.1
Ruthenium	At 0°C	752.9	12.06
Salt, Rock		136	2.18
Salt, Common		135.2	2.165
Saltpeter (Potassium Nitrate)		131.7	2.109
Samarium		480.7–486.9	7.7–7.8
Sand, of Pure Quartz, Dry		90–105	1.4–1.7
Sandstone		134–147	2.14–2.36
Selenium		268.4–299.6	4.3–4.8
Shale, Slate		168.6–181.0	2.7–2.9
Shellac		67.4–70.5	1.08–1.13
Silicon, Crystal	At 20°C	151.1	2.42
Silver, Cast		650.5–657.4	10.42–10.53
Slags		125–240	2.0–3.9
Slags, Bank Screenings		98–117	1.56–1.87
Slate (See Shale)		162–205	2.6–3.3
Soapstone, Talc		162–175	2.6–2.8
Soda Ash (Sodium Carbonate) 66%		106	1.7
Sodium	At 20°C	60.6	0.971
Soil		70	1.1
Speculum Metal (67 Cu, 33 Sn)		536.87	8.60
Spelter (Zinc)		439.5–447.0	7.04–7.16
Steam at 212°F		0.03807	(0.472)
Steel (99 Fe, 1 C)		488.80	7.83
Sulfur		124.9–131.1	2.0–2.1
Talc (Soapstone)		168–174	2.7–2.8
Tar, Bituminous		66	1.02

		Lbs. Per Cu. Ft.	Specific Gravity
Tellurium, Crystal		390.2	6.25
Thallium		740.4	11.86
Thorium		705.4–730.4	11.3–11.7
Tin, White Cast		455.1	7.29
Tin, Gray		362.1	5.8
Titanium	At 18°C	280.9	4.5
Tungsten		1161.1–1192.4	18.6–19.1
Uranium	At 13°C	1167.4	18.7
Vanadium	At 20°C	372.1	5.96
Water, Pure	At 4°C	62.43	1.00
Water, Sea		64	1.02–1.03
White Metal (Babbitt)		454	7.27
Wood, Ash		40–53	0.65–0.85
Wood, Birch		32–48	0.51–0.77
Wood, Cedar		30–35	0.49–0.57
Wood, Chestnut		41	0.66
Wood, Elm		34–37	0.54–0.60
Wood, Fir		25–26	0.41–0.42
Wood, Hemlock		27–30	0.43–0.48
Wood, Lignum Vitae		73–83	1.17–1.33
Wood, Locust		42–44	0.67–0.71
Wood, Maple		39–47	0.62–0.75
Wood, Oak		37–56	0.60–0.90
Wood, Pine, Pitch		52–53	0.83–0.85
Wood, Pine, White		22–31	0.35–0.50
Wood, Pine, Yellow		23–37	0.37–0.60
Wood, Poplar		22–31	0.35–0.50
Wood, Spruce		30–44	0.48–0.70
Wood, Sycamore		24–37	0.40–0.60
Wood, Walnut		40–43	0.64–0.70
Wood's Metal		659.23	10.56
Zinc, Cast		439.5–447.0	7.04–7.16
Zinc, Wrought		448.9	7.19
Zirconium		402.0	6.44

CHEMICAL COMPOSITIONS OF CARBON AND ALLOY AISI, SAE AND NE STEELS

SYSTEM OF IDENTIFICATION

A system of symbols is used to identify the grade classifications of standard steels. In those symbols capital letter prefixes are used to indicate the steel-making process. Numbers are used to indicate grades of steel by chemical composition. Lower case letters are used as suffixes to indicate various special requirements affecting quality. The application and meaning of the prefix letter designations are described on page D 43.

Numerical Designations. A four-numeral series designates carbon steel or alloy steel specified to chemical composition ranges. Five numerals are used to designate certain types of alloy steels.

The last two digits of the four-numeral series are intended, so far as feasible, to indicate the approximate middle of the carbon range; for example, 20 represents a range of 0.18 to 0.23 per cent. It is necessary however to deviate from this rule and to interpolate numbers in the case of some carbon ranges; and for variations in manganese, phosphorus, sulphur, chromium, or other elements.

The first two digits of the four-numeral series for the various grades of steel and their meaning are as follows:

Series Designation	*Types and Classes*
10xx	Basic and acid open-hearth and acid bessemer carbon steel grades, nonsulphurized and nonphosphorized.
11xx	Basic open-hearth and acid bessemer carbon steel grades, sulphurized but not phosphorized.
12xx	Basic open-hearth carbon steel grades, phosphorized.
13xx	Manganese 1.60 to 1.90 per cent
23xx	Nickel 3.50 per cent
25xx	Nickel 5.00 per cent
30xx	Nickel 0.70 per cent—Chromium 0.70 per cent
31xx	Nickel 1.25 per cent—Chromium 0.60 per cent
32xx	Nickel 1.75 per cent—Chromium 1.00 per cent
33xx	Nickel 3.50 per cent—Chromium 1.50 per cent
40xx	Molybdenum
41xx	Chromium-molybdenum
43xx	Nickel-chromium-molybdenum
46xx	Nickel 1.65 per cent—Molybdenum 0.25 per cent
48xx	Nickel 3.25 per cent—Molybdenum 0.25 per cent
50xx	Low chromium
51xx	Medium chromium
52xxx	Chromium, high-carbon
61xx	Chromium-vanadium
80xx	Manganese 1.15 per cent—Molybdenum 0.15 per cent
84xx	Manganese 1.45 per cent—Molybdenum 0.35 per cent
86xx	Nickel 0.55 per cent—Chromium 0.50 per cent—Molybdenum 0.20 per cent
87xx	Nickel 0.55 per cent—Chromium 0.50 per cent—Molybdenum 0.25 per cent
92xx	Manganese 0.80 per cent—Silicon 2.00 per cent
94xx	Manganese 0.95 to 1.15 per cent—Silicon 0.50 per cent—Nickel 0.35 per cent—Chromium 0.30 per cent—Molybdenum 0.12 per cent
95xx	Manganese 1.35 per cent—Silicon 0.50 per cent—Nickel 0.55 per cent—Chromium 0.50 per cent—Molybdenum 0.20 per cent
96xx	Manganese 1.35 per cent—Silicon 0.50 per cent—Chromium 0.50 per cent

CARBON STEELS

AISI No.	C	Mn	P. Max.	S. Max.	SAE No.
C 1005	.06 max.	.35 max.	.040	.050	—
C 1006	.08 max.	.25- .40	.040	.050	—
C 1008	.10 max	.30- .50	.040	.050	1008
CB 1008	.10 max.	—	—	—	—
C 1009	.07- .12	.25- 40	.040	.050	—
C 1010	.08- .13	.30- .50	.040	.050	1010
C 1011	.08- .13	.40- .60	.040	.050	—
C 1012	.10- .15	.30- .50	.040	.050	—
CB 1012	.15 max.	—	—	—	—
C 1013	.11- .16	.60- .90	.040	.050	—
C 1014	.13- .18	.40- .60	.040	.050	—
C 1015	.13- .18	.30- .50	.040	.050	1015
C 1016	.13- .18	.60- .90	.040	.050	X 1015 1016
C 1017	.15- .20	.40- .60	.040	.050	—
CB 1017	.10- .25	—	—	—	—
C 1018	.15- .20	.60- .90	.040	.050	—
C 1019	.15- .20	.70-1.00	.040	.050	—
C 1020	.18- .23	.30- .50	.040	.050	1020
C 1021	.18- .23	.40- .60	.040	.050	—
C 1022	.18- .23	.70-1.00	.040	.050	X 1020 1022
C 1023	.20- .25	.30- .50	.040	.050	—
C 1024	.20- .26	1.35-1.65	.040	.050	1024
C 1025	.22- .28	.30- .50	.040	.050	1025
C 1026	.22- .28	.40- .60	.040	.050	—
C 1027	.24- .30	.40- .60	.040	.050	—
C 1029	.25- .31	.60- .90	.040	.050	—
C 1030	.28- .34	.60- .90	.040	.050	1030
C 1031	.28- .34	.40- .60	.040	.050	—
CB 1032	.25- .40	—	—	—	—
C 1033	.30- .36	.60- .90	.040	.050	—
C 1034	.32- .38	.50- .70	.040	.050	—
D 1034	.32- .38	.50- .70	.050	.050	—
C 1035	.32- .38	.60- .90	.040	.050	1035
C 1036	.32- .39	1.20-1.50	.040	.050	1036
C 1038	.35- .42	.60- .90	.040	.050	—
C 1040	.37- .44	.60- .90	.040	.050	1040
C 1041	.36- .44	1.35-1.65	.040	.050	—
C 1042	.40- .47	.60- .90	.040	.050	—
C 1043	.40- .47	.70-1.00	.040	.050	—
C 1044	.43- .50	.50- .70	.040	.050	—
C 1045	.43- .50	.60- .90	.040	.050	1045
C 1046	.43- .50	.70-1.00	.040	.050	—
D 1049	.43- .50	.50- .70	.050	.050	—
C 1050	.48- .55	.60- .90	.040	.050	1050
C 1051	.45- .56	.85-1.15	.040	.050	—
C 1052	.47- .55	1.20-1.50	.040	.050	1052
C 1054	.50- .60	.50- .70	.040	.050	—
D 1054	.50- .60	.50- .70	.050	.050	—
C 1055	.50- .60	.60- .90	.040	.050	1055
C 1057	.50- .61	.85-1.15	.040	.050	—

Continued on next page

STEEL SPECIFICATIONS — Continued

CARBON STEELS — Continued

AISI No.	C	Mn	P. Max.	S. Max.	SAE No.
C 1059	.55- .65	.50- .70	.040	.050	—
D 1059	.55- .65	.50- .70	.050	.050	—
C 1060	.55- .65	.60- .90	.040	.050	1060
C 1060	.55- .65	.60- .80	.040	.050	—
C 1061	.54- .65	.75-1.05	.040	.050	—
C 1062	.54- .65	.85-1.15	.040	.050	—
C 1064	.60- .70	.50- .70	.040	.050	—
D 1064	.60- .70	.50- .70	.050	.050	—
C 1066	.60- .71	.80-1.10	.040	.050	X 1065 1066
C 1068	.65- .75	.50 max.	.040	.050	—
C 1069	.65- .75	.50- .70	.040	.050	—
D 1069	.65- .75	.40- .60	.050	.050	—
C 1070	.65- .75	.70-1.00	.040	.050	1070
C 1074	.70- .80	.50- .70	.040	.050	—
D 1074	.70- .80	.40- .60	.050	.050	—
C 1075	.70- .80	.60- .80	.040	.050	—
C 1076	.70- .80	.60- .90	.040	.050	—
C 1078	.72- .85	.30- .50	.040	.050	—
D 1078	.70- .85	.30- .50	.050	.050	—
C 1080	.75- .88	.60- .90	.040	.050	1080
D 1083	.80- .95	.30- .50	.050	.050	—
C 1084	.80- .93	.60- .90	.040	.050	—
C 1085	.80- .93	.70-1.00	.040	.050	1085
C 1086	.82- .95	.30- .50	.040	.050	—
C 1090	.85-1.00	.60- .90	.040	.050	—
C 1095	.90-1.05	.30- .50	.040	.050	1095
D 1095	.90-1.05	.30- .50	.050	.050	—
B 1006	.08 max.	.45 max.	.110 max.	.060 max.	—
B 1008	.10 max.	.30- .50	.110 max.	.060 max.	—
B 1010	.07- .13	.30- .50	.07- .110	.070 max.	—
B 1011	.13 max.	.50- .70	.110 max.	.060 max.	—

CARBON STEELS — PHOSPHORIZED

AISI No.	C	Mn	P. Max.	S. Max.	SAE No.
C 1205	.08 max.	.25- .40	.040-.070	.050 max.	—
C 1206	.08 max.	.25- .40	.060-.100	.050 max.	—
C 1209	.08- .13	.30- .50	.040-.070	.050 max.	—
C 1210	.08- .13	.30- .50	.060-.100	.050 max.	—

NOTE 1: When silicon is specified in standard basic open-hearth steels, silicon may be ordered only as 0.10 per cent maximum; 0.10 to 0.20 per cent; or 0.15 to 0.30 per cent. In the case of many grades of basic open-hearth steel, special practices are required in order to comply with a specification including silicon.

NOTE 2: Acid bessemer steel is not furnished with specified silicon content.

NOTE 3: Phosphorized steel is not subject to check analysis for phosphorus.

NOTE 4: Acid open-hearth steels may be ordered with a silicon content of 0.10 to 0.25 per cent, or 0.15 to 0.35 per cent.

Prefix Letter Designations for AISI Steels: The prefix letters B, C, CB, and D designate the principal steel-making processes as follows:

B — Acid bessemer carbon steel.

C — Basic open-hearth carbon steel.

CB — Either acid bessemer or basic open-hearth carbon steel.

D — Acid open-hearth.

FREE CUTTING STEELS

AISI No.	C	Mn	P	S	SAE No.
C 1108	.08-.13	.50- .70	.045 max.	.07-.12	—
C 1109	.08-.13	.60- .90	.045 max.	.08-.13	—
C 1110	.08-.13	.60- .90	.045 max.	.10-.15	—
C 1111	.08-.13	.60- .90	.045 max.	.16-.23	—
C 1112	.10-.16	1.00-1.30	.045 max.	.08-.13	—
C 1113	.10-.16	1.00-1.30	.045 max.	.24-.33	—
C 1115	.13-.18	.70-1.00	.045 max.	.08-.13	—
C 1116	.13-.18	.70-1.00	.045 max.	.10-.15	—
C 1117	.14-.20	1.00-1.30	.045 max.	.08-.13	X 1314 1117
C 1118	.14-.20	1.30-1.60	.045 max.	.08-.13	X 1315 1118
C 1119	.14-.20	1.35-1.65	.045 max.	.16-.23	—
C 1120	.18-.23	.60- .90	.045 max.	.08-.13	—
C 1121	.18-.23	.70-1.00	.045 max.	.08-.13	—
C 1122	.17-.23	1.35-1.65	.045 max.	.08-.13	—
C 1132	.27-.34	1.35-1.65	.045 max.	.08-.13	X 1330 1132
C 1137	.32-.39	1.35-1.65	.045 max.	.08-.13	X 1335 1137
C 1141	.37-.45	1.35-1.65	.045 max.	.08-.13	X 1340 1141
C 1144	.40-.48	1.35-1.65	.045 max.	.24-.33	—
C 1145	.42-.49	.70-1.00	.045 max.	.04-.07	1145
B 1106	.09 max.	.50 max.	.110 max.	.040-.090	—
B 1110	.13 max.	.60 max.	.110 max.	.045-.075	—
B 1111	.08-.13	.60- .90	.090-.130	.100-.150	1111
B 1112	.08-.13	.60- .90	.090-.130	.160-.230	1112
B 1113	.08-.13	.60- .90	.090-.130	.240-.330	X 1112 1113
C 1217	.14-.19	.70-1.00	.090-.130	.200-.290	—

NOTE 1: Special practice is necessary to comply with a specification of a minimum silicon content in a sulphurized steel when the maximum limit of sulphur is over 0.055 per cent.

NOTE 2: Sulphurized steel is not subject to check analysis for sulphur.

NOTE 3: Acid bessemer steel is not furnished with specified silicon content.

NOTE 4: Phosphorized steel is not subject to check analysis for phosphorus.

The prefix letter "B" designates acid bessemer carbon steel and "C" designates basic open-hearth carbon steel.

MANGANESE STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	Mo	SAE No.
A 1320	.18-.23	1.60-1.90	.040	.040	.20-.35	—	—	—	1320
A 1330	.28-.33	1.60-1.90	.040	.040	.20-.35	—	—	—	1330
A 1335	.33-.38	1.60-1.90	.040	.040	.20-.35	—	—	—	1335
A 1340	.38-.43	1.60-1.90	.040	.040	.20-.35	—	—	—	1340
A 1345	.43-.48	1.60-1.90	.040	.040	.20-.35	—	—	—	—
A 1350	.48-.53	1.60-1.90	.040	.040	.20-.35	—	—	—	—

NICKEL STEELS

			*	*	*				
A 2317	.15-.20	.40-.60	.040	.040	.20-.35	3.25-3.75	—	—	2315 2317
A 2330	.28-.33	.60-.80	.040	.040	.20-.35	3.25-3.75	—	—	2330
A 2335	.33-.38	.60-.80	.040	.040	.20-.35	3.25-3.75	—	—	—
A 2340	.38-.43	.70-.90	.040	.040	.20-.35	3.25-3.75	—	—	2340
A 2345	.43-.48	.70-.90	.040	.040	.20-.35	3.25-3.75	—	—	2345
E 2512	.09-.14	.45-.60	.025	.025	.20-.35	4.75-5.25	—	—	—
A 2515	.12-.17	.40-.60	.040	.040	.20-.35	4.75-5.25	—	—	2515
E 2517	.15-.20	.45-.60	.025	.025	.20-.35	4.75-5.25	—	—	—

*See notes on page D46.

STEEL SPECIFICATIONS — Continued

NICKEL CHROMIUM STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	Mo	SAE No.
A 3045	.43-.48	.75-.95	.040	.040	.20-.35	.60- .80	.60- .80	—	—
A 3115	.13-.18	.40-.60	.040	.040	.20-.35	1.10-1.40	.55- .75	—	3115
A 3120	.17-.22	.60-.80	.040	.040	.20-.35	1.10-1.40	.55- .75	—	3120
A 3130	.28-.33	.60-.80	.040	.040	.20-.35	1.10-1.40	.55- .75	—	3130
A 3135	.33-.38	.60-.80	.040	.040	.20-.35	1.10-1.40	.55- .75	—	3135
A 3140	.38-.43	.70-.90	.040	.040	.20-.35	1.10-1.40	.55- .75	—	3140
A 3141	.38-43	.70-.90	.040	.040	.20-.35	1.10-1.40	.70- .90	—	X 3140 3141
A 3145	.43-.48	.70-.90	.040	.040	.20-.35	1.10-1.40	.70- .90	—	3145
A 3150	.48-.53	.70-.90	.040	.040	.20-.35	1.10-1.40	.70- .90	—	3150
A 3240	.38-.43	.40-.60	.040	.040	.20-.35	1.65-2.00	.90-1.20	—	—
A 3240	.38-.45	.40-.60	.040	.040	.20-.35	1.65-2.00	.90-1.20	—	3240
E 3310	.08-.13	.45-.60	.025	.025	.20-.35	3.25-3.75	1.40-1.75	—	3312** 3310
E 3316	.14-.19	.45-.60	.025	.025	.20-.35	3.25-3.75	1.40-1.75	—	—

**Electric Furnace.

MOLYBDENUM STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	Mo	SAE No.
A 4023	.20-.25	.70- .90	.040	.040	.20-.35	—	—	.20-.30	4023
A 4024	.20-.25	.70- .90	.040	.035-.050	.20-.35	—	—	.20-.30	—
A 4027	.25-.30	.70- .90	.040	.040	.20-.35	—	—	.20-.30	4027
A 4028	.25-.30	.70- .90	.040	.035-.050	.20-.35	—	—	.20-.30	—
A 4032	.30-.35	.70- .90	.040	.040	.20-.35	—	—	.20-.30	4032
A 4037	.35-.40	.75-1.00	.040	.040	.20-.35	—	—	.20-.30	4037
A 4042	.40-.45	.75-1.00	.040	.040	.20-.35	—	—	.20-.30	4042
A 4047	.45-.50	.75-1.00	.040	.040	.20-.35	—	—	.20-.30	4047
A 4063	.60-.67	.75-1.00	.040	.040	.20-.35	—	—	.20-.30	4063
A 4068	.64-.72	.75-1.00	.040	.040	.20-.35	—	—	.20-.30	4068
A 4119	.17-.22	.70- .90	.040	.040	.20-.35	—	.40- .60	.20-.30	4119
A 4120	.17-.22	.70- .90	.040	.040	.20-.35	—	.60- .80	.20-.30	—
A 4125	.23-.28	.70- .90	.040	.040	.20-.35	—	.40- .60	.20-.30	4125
A 4130	.28-.33	.40- .60	.040	.040	.20-.35	—	.80-1.10	.15-.25	X4130 4130
A 4131	.28-.33	.50- .70	.040	.040	.20-.35	—	.80-1.00	.14-.19	—
E 4132	.30-.35	.40- .60	.025	.025	.20-.35	—	.80-1.10	.18-.25	—
A 4134	.32-.37	.40- .60	.040	.040	.20-.35	—	.80-1.10	.15-.25	—
E 4135	.33-.38	.70- .90	.025	.025	.20-.35	—	.80-1.10	.18-.25	—
A 4137	.35-.40	.70- .90	.040	.040	.20-.35	—	.80-1.10	.15-.25	4137
E 4137	.35-.40	.70- .90	.025	.025	.20-.35	—	.80-1.10	.18-.25	—
A 4140	.38-.43	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.15-.25	4140
A 4141	.38-.43	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.14-.19	—
A 4142	.40-.45	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.15-.25	—
A 4143	.40-.45	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.30-.40	—
A 4145	.43-.48	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.15-.25	4145
A 4147	.45-.50	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.15-.25	—
A 4150	.46-.53	.75-1.00	.040	.040	.20-.35	—	.80-1.10	.15-.25	4150
E 4150	.48-.53	.70- .90	.025	.025	.20-.35	—	.80-1.10	.20-.27	—
A 4317	.15-.20	.45- .65	.040	.040	.20-.35	1.65-2.00	.40- .60	.20-.30	—
A 4320	.17-.22	.45- .65	.040	.040	.20-.35	1.65-2.00	.40- .60	.20-.30	4320

*See notes on next page.

Continued on next page

STEEL SPECIFICATIONS — Continued

MOLYBDENUM STEELS — Continued

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	Mo	SAE No.
A 4337	.35-.40	.60- .80	.040	.040	.20-.35	1.65-2.00	.60- .80	.30-.40	—
E 4337	.35-.40	.60- .80	.025	.025	.20-.35	1.65-2.00	.70- .90	.23-.30	—
A 4340	.38-.43	.60- .80	.040	.040	.20-.35	1.65-2.00	.70- .90	.20-.30	X4340 4340
E 4342	.40-.45	.60- .80	.025	.025	.20-.35	1.65-2.00	.70- .90	.23-.30	—
A 4608	.06-.11	.40 max.	.040	.040	.25 max.	1.40-1.75	—	.15-.25	—
A 4615	.13-.18	.45- .65	.040	.040	.20-.35	1.65-2.00	—	.20-.30	4615
E 4617	.15-.20	.45- .65	.025	.025	.20-.35	1.65-2.00	—	.20-.27	—
A 4620	.17-.22	.45- .65	.040	.040	.20-.35	1.65-2.00	—	.20-.30	4620
E 4620	.17-.22	.45- .60	.025	.025	.20-.35	1.65-2.00	—	.20-.27	—
A 4621	.18-.23	.70- .90	.040	.040	.20-.35	1.65-2.00	—	.20-.30	—
A 4640	.38-.43	.60- .80	.040	.040	.20-.35	1.65-2.00	—	.20-.30	4640
E 4640	.38-.43	.60- .80	.025	.025	.20-.35	1.65-2.00	—	.20-.27	—
A 4645	.43-.48	.60- .80	.040	.040	.20-.35	1.65-2.00	—	.20-.30	—
A 4815	.13-.18	.40- .60	.040	.040	.20-.35	3.25-3.75	—	.20-.30	4815
A 4820	.18-.23	.50- .70	.040	.040	.20-.35	3.25-3.75	—	.20-.30	4820

CHROMIUM STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	Mo	SAE No.
A 5045	.43- .48	.70-.90	.040	.040	.20-.35	—	.55- .75	—	—
A 5120	.17- .22	.70-.90	.040	.040	.20-.35	—	.70- .90	—	5120
A 5130	.28- .33	.70-.90	.040	.040	.20-.35	—	.80-1.10	—	—
A 5140	.38- .43	.70-.90	.040	.040	.20-.35	—	.70- .90	—	5140
A 5145	.43- .48	.70-.90	.040	.040	.20-.35	—	.70- .90	—	—
A 5150	.48- .55	.70-.90	.040	.040	.20-.35	—	.70- .90	—	5150
A 5152	.45- .55	.70-.90	.040	.040	.20-.35	—	.90-1.20	—	—
E 52095	.95-1.10	.25-.45	.025	.025	.20-.35	—	.40- .60	—	—
E 52098	.95-1.10	.25-.45	.025	.025	.20-.35	—	.90-1.15	—	—
E 52100	.95-1.10	.25-.45	.025	.025	.20-.35	—	1.20-1.50	—	—
E 52101	.95-1.10	.25-.45	.025	.025	.20- 35	—	1.30-1.60	—	—

CHROMIUM VANADIUM STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	V	SAE No.
A 6120	.17-.22	.70-.90	.040	.040	.20-.35	—	.70- .90	.10 min.	—
A 6145	.43-.48	.70-.90	.040	.040	.20-.35	—	.80-1.10	.15 min.	—
E 6150	.47-.53	.70-.90	.025	.025	.20-.35	—	.80-1.10	.15 min.	—
A 6152	.48-.55	.70-.90	.040	.040	.20-.35	—	.80-1.10	.10 min.	—

SILICON MANGANESE STEELS

AISI No.	C	Mn	P * Max.	S * Max.	* Si	Ni	Cr	V	SAE No.
A 9255	.50-.60	.70- .95	.040	.040	1.80-2.20	—	—	—	—
A 9260	.55-.65	.70-1.00	.040	.040	1.80-2.20	—	—	—	—
A 9262	.55-.65	.70-1.00	.040	.040	1.80-2.20	—	.20-.40	—	—

* Lowest standard maximum phosphorus or sulphur content for acid open-hearth or acid electric furnace alloy steel is 0.05 per cent each. Lowest standard minimum for silicon is 0.15 per cent.

The prefix letter "A" designates basic open-hearth alloy steels and "E" designates electric furnace alloy steels.

NATIONAL EMERGENCY STEEL COMPOSITIONS

May 26, 1944

Conditions surrounding the production of alloy steels have made necessary certain changes in and additions to the chemical composition limits of the National Emergency (N.E.) Steels.

The modifications were made by representatives of the Metallurgical and Conservation Branch of the Steel Division of the War Production Board; the Office of the Chief of Ordnance, Technical Division, U. S. Army; and members of the Iron and Steel Division of the Society of Automotive Engineers, the S.A.E. War Engineering Board and the Technical Committee on Alloy Steel of American Iron and Steel Institute.

The changes were made primarily to permit greater consumption of nickel-chromium-molybdenum scrap and also to make available triple alloy steels having hardenability characteristics intermediate between previously existing series. To accomplish those ends, the following changes in and additions to National Emergency steel compositions have been made:

1. The 8700 series has been restored in a wider variety of carbon ranges.

2. A new series, the 9700 series, has been established having hardenability characteristics similar to those of the 4000 series.

3. A new series, the 9800 series, has been established having hardenability characteristics about half way between those of the 8700 series and those of the 4300 series, in the thorough-hardening carbon ranges.

4. A new series, the 9900 series, has been established in the low carbon ranges, designed especially for carburizing and having hardenability characteristics similar to or slightly in excess of the 8700 series.

CARBON-MANGANESE STEELS

	C	*Mn*	*Si*
NE 1330	0.28/0.33	1.60/1.90	0.20/0.35
NE 1335	0.33/0.38	1.60/1.90	0.20/0.35
NE 1340	0.38/0.43	1.60/1.90	0.20/0.35
NE 1345	0.43/0.48	1.60/1.90	0.20/0.35
NE 1350	0.48/0.53	1.60/1.90	0.20/0.35

NICKEL-CHROMIUM-MOLYBDENUM STEELS

	C	*Mn*	*Si*	*Ni*	*Cr*	*Mo*
NE 8612	0.10/0.15	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8615	0.13/0.18	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8617	0.15/0.20	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8620	0.18/0.23	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8622	0.20/0.25	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8625	0.23/0.28	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8627	0.25/0.30	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8630	0.28/0.33	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8632	0.30/0.35	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8635	0.33/0.38	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8637	0.35/0.40	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8640	0.38/0.43	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8642	0.40/0.45	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8645	0.43/0.48	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8647	0.45/0.50	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8650	0.48/0.53	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.15/0.25
NE 8712	0.10/0.15	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8715	0.13/0.18	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8717	0.15/0.20	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8720	0.18/0.23	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8722	0.20/0.25	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8725	0.23/0.28	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8727	0.25/0.30	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8730	0.28/0.33	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8732	0.30/0.35	0.70/0.90	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8735	0.33/0.38	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8737	0.35/0.40	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8740	0.38/0.43	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8742	0.40/0.45	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8745	0.43/0.48	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8747	0.45/0.50	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 8750	0.48/0.53	0.75/1.00	0.20/0.35	0.40/0.70	0.40/0.60	0.20/0.30
NE 9415	0.13/0.18	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9417	0.15/0.20	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9420	0.18/0.23	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9422	0.20/0.25	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9425	0.23/0.28	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9427	0.25/0.30	0.80/1.10	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9430	0.28/0.33	0.90/1.20	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9432	0.30/0.35	0.90/1.20	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9435	0.33/0.38	0.90/1.20	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9437	0.35/0.40	0.90/1.20	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9440	0.38/0.43	0.90/1.20	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9442	0.40/0.45	1.00/1.30	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9445	0.43/0.48	1.00/1.30	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9447	0.45/0.50	1.20/1.50	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9450	0.48/0.53	1.20/1.50	0.20/0.35	0.30/0.60	0.30/0.50	0.08/0.15
NE 9722	0.20/0.25	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9727	0.25/0.30	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9732	0.30/0.35	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9737	0.35/0.40	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9742	0.40/0.45	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9745	0.43/0.48	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25

NICKEL-CHROMIUM-MOLYBDENUM STEELS (Cont.)

	C	*Mn*	*Si*	*Ni*	*Cr*	*Mo*
NE 9747	0.45/0.50	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9750	0.48/0.53	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9763	0.60/0.67	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9768	0.64/0.72	0.50/0.80	0.20/0.35	0.40/0.70	0.10/0.25	0.15/0.25
NE 9830	0.28/0.33	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9832	0.30/0.35	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9835	0.33/0.38	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9837	0.35/0.40	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9840	0.38/0.43	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9842	0.40/0.45	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9845	0.43/0.48	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9847	0.45/0.50	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9850	0.48/0.53	0.70/0.90	0.20/0.35	0.85/1.15	0.70/0.90	0.20/0.30
NE 9912	0.10/0.15	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30
NE 9915	0.13/0.18	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30
NE 9917	0.15/0.20	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30
NE 9920	0.18/0.23	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30
NE 9922	0.20/0.25	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30
NE 9925	0.23/0.28	0.50/0.70	0.20/0.35	1.00/1.30	0.40/0.60	0.20/0.30

SILICON-MANGANESE AND SILICON-MANGANESE-CHROMIUM STEELS

	C	*Mn*	*Si*	*Cr*
NE 9255	0.50/0.60	0.70/0.95	1.80/2.20	—
NE 9260	0.55/0.65	0.70/1.00	1.80/2.20	—
NE 9261	0.55/0.65	0.70/1.00	1.80/2.20	0.10/0.25
NE 9262	0.55/0.65	0.70/1.00	1.80/2.20	0.25/0.40

CARBON-CHROMIUM STEELS

	C	*Mn*	*Si*	*Cr*	*Ni*	*Mo*
NE 52100A	0.95/1.10	0.25/0.45	0.20/0.35	1.30/1.60	0.35 max.	0.08 max.
NE 52100B	0.95/1.10	0.25/0.45	0.20/0.35	0.90/1.15	0.35 max.	0.08 max.
NE 52100C	0.95/1.10	0.25/0.45	0.20/0.35	0.40/0.60	0.35 max.	0.08 max.

NOTE 1. When electric furnace steel is specified, phosphorus and sulphur contents are to be 0.025% maximum each.

NOTE 2. All National Emergency steels are subject to the conditions outlined for standard steels as listed in Steel Product Manual No. 10 covering alloy steels, pages 14 to 17 inclusive, and page 26. Large sizes are subject to modification of carbon content only to a range of 0.10 as outlined on pages 23 and 26 of the same Manual.

TENTATIVE CLASSIFICATION OF
AUSTENITE GRAIN SIZE IN STEELS[1]

A.S.T.M. Designation: E 19 – 39 T

Issued, 1938; Revised, 1939[2]

This Tentative Standard of the American Society for Testing Materials is, under its Regulations, subject to annual revision. Suggestions for revision should be addressed to the Society, 260 S. Broad St., Philadelphia, Pa.

Scope

1. This classification for austenite grain size comprises two sets of charts, one of them in idealized form intended to be used with any procedure for determining austenite grain size (Plate I), the other consisting of a series of photomicrographs showing the structures found in the carburized case in a carburizing (McQuaid-Ehn) test (Plate II). These two charts cover the same range of sizes, with identical designations (Nos. 1 to 8), the use of the one or the other being a matter of individual preference. The manner of making the grain size test may of course be decisive as to which chart will be used.

Establishing Austenite Grain Size

2. As may be agreed upon between the manufacturer and the purchaser, austenite grain size (see Notes 1 and 2) shall in this classification be established either:

(*a*) By carburizing at 1700° F. (925° C.) for 8 hr. (the McQuaid-Ehn test), which is recommended for carburizing grades, and often employed for other grades as well, or

(*b*) By heating at a temperature not over 50° F. (28° C.) above the normal heat-treating temperature and for not over 50 per cent more than the normal heat-treating time, the normal values being those mutually agreed upon.

The rate of cooling depends on the method of treatment, as will be evident from the methods described in Section 3.

Note 1.—Numerous methods are in use for establishing austenite grain size, and a knowledge of grain-coarsening behaviors is helpful in deciding which method to use. The size of austenite grains, in any particular steel, depends primarily on the temperature to which that steel is heated and the time it is held at the temperature. It should be remembered that the atmosphere in heating may affect the grain-growth behavior at the outside of the piece.

Note 2.—Austenite grain size is influenced by most previous treatments to which steel may have been subjected, as, for example, quenching, normalizing, hot working, and cold working. It is therefore advisable, when testing for austenite grain size, to consider the effects of prior or subsequent treatments on the precise piece (or typical piece) which is under consideration.

Revealing the Grain Size

3. For revealing austenite grain size the following methods (See Explanatory Note) are generally used:

(*a*) By outlining the grains with cementite, as in carburizing (McQuaid-Ehn test) or as in high-carbon steels, or

(*b*) By outlining the grains with ferrite, as in the hypoeutectoid zone in carburizing, or in medium-carbon steels generally, or by

TABLE I.—GRAIN SIZE RELATIONSHIPS, ACTUAL AND AS OBSERVED AT 100 DIAMETERS MAGNIFICATION.

A.S.T.M. Grain-Size Number*	Number of Grains per Square Inch as Viewed at 100 Diameters		Calculated Diameter of Equivalent Spherical Grain (not magnified)		Calculated Mean Average of Cross-Section of Grain (not magnified), sq. in.
	Mean	Range	in.	mm.	
1.....	1	$\frac{3}{4}$ to $1\frac{1}{2}$	0.0113	0.287	0.000 1
2.....	2	$1\frac{1}{2}$ to 3	0.00800	0.203	0.000 05
3.....	4	3 to 6	0.00567	0.144	0.000 025
4.....	8	6 to 12	0.00400	0.101	0.000 012 5
5.....	16	12 to 24	0.00283	0.0718	0.000 006 25
6.....	32	24 to 48	0.00200	0.0507	0.000 003 13
7.....	64	48 to 96	0.00142	0.0359	0 000 001 56
8.....	128	96 to 192	0.00100	0.0254	0.000 000 78

* With the present state of the art of steel making, the dividing line between coarse and fine is found at about No. 5 grain size.

[1] Under the standardization procedure of the Society, this classification is under the jurisdiction of the A.S.T.M. Committee E-4 on Metallography.

[2] Revision accepted by Committee E-10 on Standards, August 24, 1939. Prior to its present publication as tentative, this classification was published as standard from 1933 to 1939.

an interrupted cooling or gradient quench on low-carbon steels, or

(c) By fine pearlite outlining martensite grains, as in eutectoid steels at a not quite fully hardened zone, or

(d) By appropriate etching of fully hardened martensite, or

(e) By an oxidation method.

Measuring the Grain Size

4. The measurement of grain size shall be carried out by comparing the microscopic image at 100 diameters magnification with the standard grain size chart in Plate I or Plate II. Absolute grain sizes may be calculated from Table I, which shows the sizes as they appear in the chart and also the actual grain sizes.

NOTE.—Larger sizes Nos. 00 and 0 may be read by using a magnification of 50 diameters (instead of 100) and using grain sizes Nos. 1 and 2 on the chart, respectively. Smaller grain sizes Nos. 9 and 10 may be read by using a magnification of 200 diameters (instead of 100) and using grain sizes Nos. 7 and 8 on the chart, respectively.

Report

5. In reporting grain size, the test conditions should be stated, including the temperature and time used in establishing the austenite grain size, and the method of revealing the grain size.

Fracture Method

6. There are in use today sets of fracture standards, in which the grain size is judged from the appearance of the fracture. It has been found that the arbitrarily numbered fracture grain sizes agree very well with the arbitrarily numbered grain sizes presented in Plate I. This coincidence makes the fracture grain sizes interchangeable with the austenite grain sizes determined microscopically (except that "duplexing" or mixed grain size is not readily discernible in fractures). The sizes observed microscopically shall be considered the primary standard, since they can be determined with measuring instruments.

EXPLANATORY NOTE

NOTE.—Details of the five methods referred to in Section 3 for ascertaining austenite grain size are briefly as follows:

(a) In the hypereutectoid zone of a McQuaid-Ehn test, or in hypereutectoid steels cooled from the austenitic condition, the austenite grain size is outlined by the cementite which precipitated in the grain boundaries. It is therefore possible to read the grain size by etching the micrographic specimen with a suitable etchant,[3] such as nital or picral, or alkaline sodium picrate.

(b) Ferrite precipitates in the austenite grain boundaries, thus indicating the austenite grain size in the hypoeutectoid zone in a McQuaid-Ehn test (see Plate II). Ferrite similarly outlines the former austenite grains in a medium-carbon steel (say 0.50 per cent carbon), when it has been cooled slowly from the austenite range. In low-carbon steels (say 0.20 per cent carbon), cooled slowly from the austenite range to room temperature, the amount of ferrite is so large that the former austenite grain size is masked; in this case, the steel may be cooled slowly to an intermediate temperature, to allow only a small amount of ferrite to precipitate, followed by quenching in water; an example would be a piece previously heated to 1675° F., tranferred to a furnace at perhaps 1350 to 1450° F., held at this temperature for perhaps 3 to 5 min., and then quenched in water; the austenite grain size would be revealed by small ferrite grains outlining "low carbon martensite" grains.

(c) A method applicable particularly to eutectoid steels, which cannot be judged so readily by some other methods, is either, (1) to harden a bar of such size that it is fully hardened at the outside but not quite fully hardened in the interior, or (2) to employ a "gradient quench" in which the heated piece is for a portion of its length immersed in water and therefore fully hardened, the remainder of the piece projecting above the quenching bath, being therefore not hardened. With either method (1) or method (2), there will be a small zone which is almost but not quite fully hardened. In this zone, the former austenite grains will consist of martensite grains surrounded by small amounts of fine pearlite ("nodular troostite"), thus revealing the grain size. These methods are also applicable to steels somewhat higher and lower than the eutectoid composition.

(d) The former austenite grain size may be revealed in steels fully hardened to martensite by using an etching reagent which develops contrast between the martensite grains. A reagent which has been recommended is 1 g. of picric acid, 5 ml. of HCl (sp. gr. 1.19), and 95 ml. of ethyl alcohol. Tempering for 15 min. at 450° F. prior to etching distinctly improves the contrast.

(e) The oxidation method depends on the fact that when steels are heated in an oxidizing atmosphere, oxidation takes place in part preferentially along the grain boundaries. A common procedure therefore is to polish the test specimen to a metallographic polish, heat it in air at the desired temperature for the desired length of time, and then repolish the specimen lightly so as merely to remove scale; whereupon the austenite grain boundaries are visible as outlined by oxide.

---

[3] See the Tentative Methods of Preparation of Metallographic Specimens (A.S.T.M. Designation: E 3) of the American Society for Testing Materials, 1942 Book of A.S.T.M. Standards, Part I.

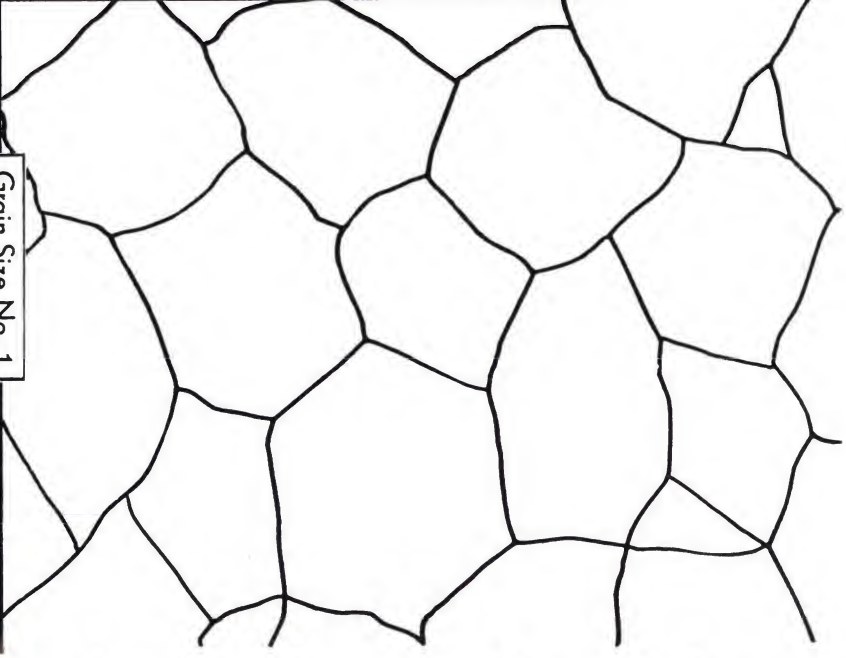
PLATE I

1942 A.S.T.M. STANDARDS, PART I

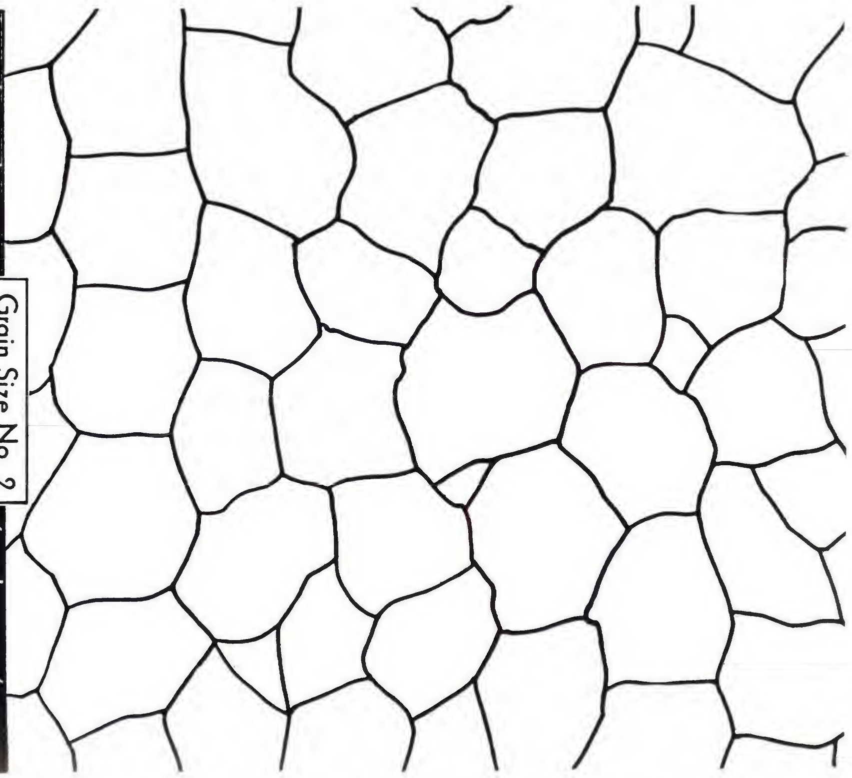
GRAIN SIZE CHART FOR CLASSIFICATION OF STEELS

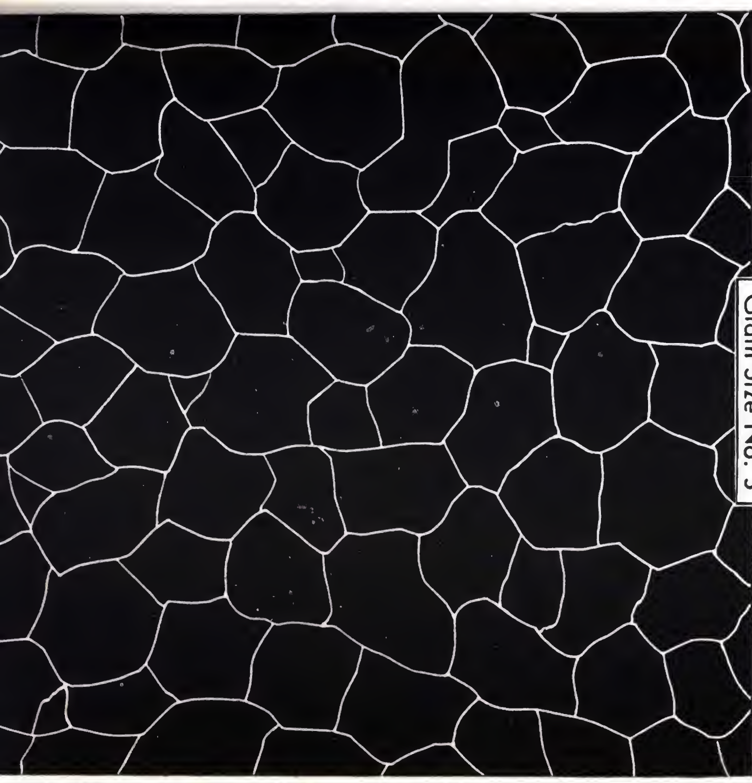
A.S.T.M. DESIGNATION: E 19

Grain Size No. 1

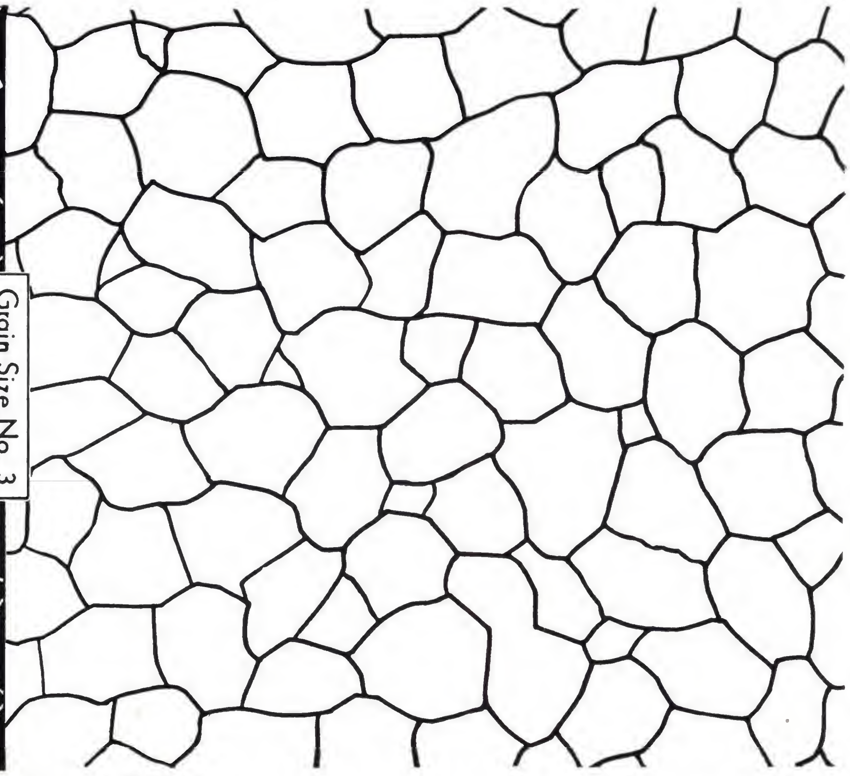


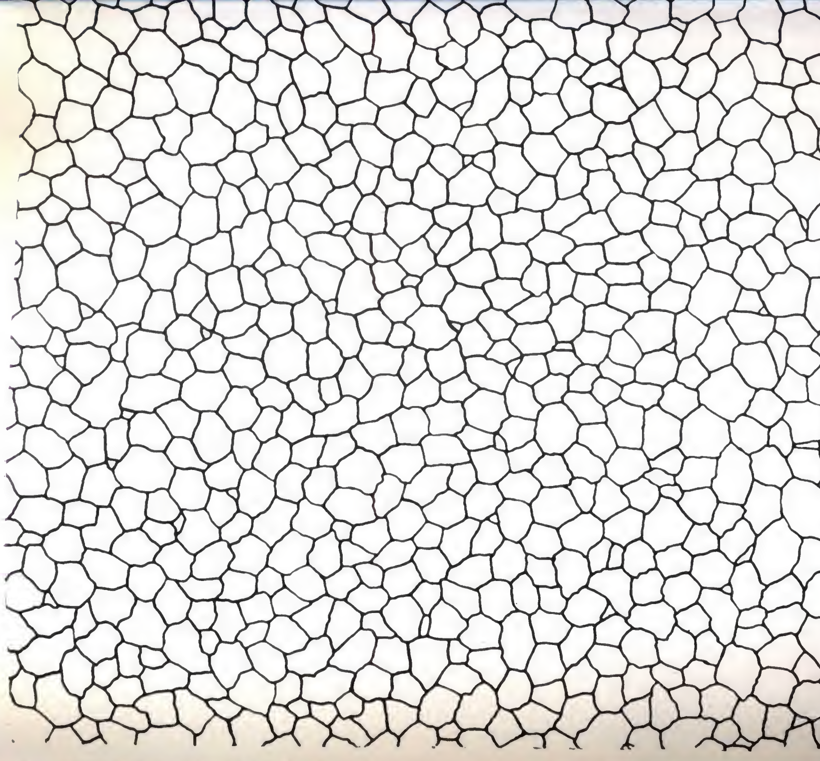
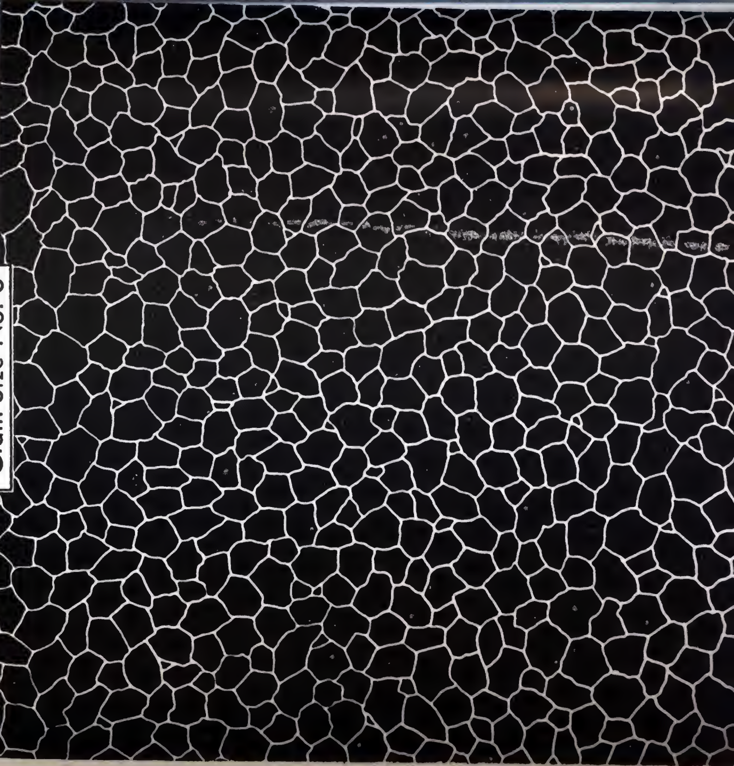
Grain Size No. 2



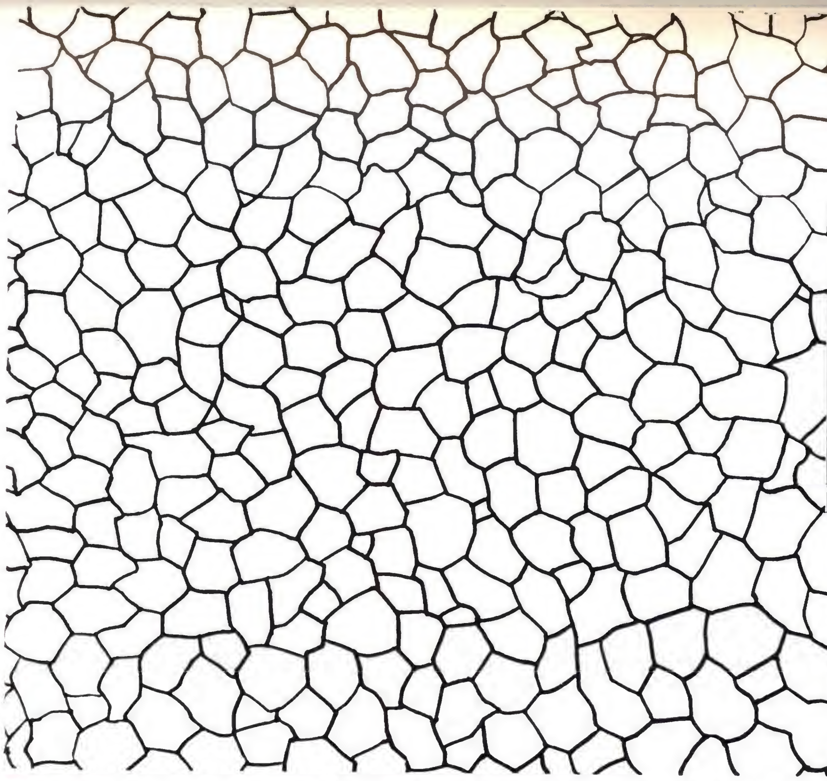
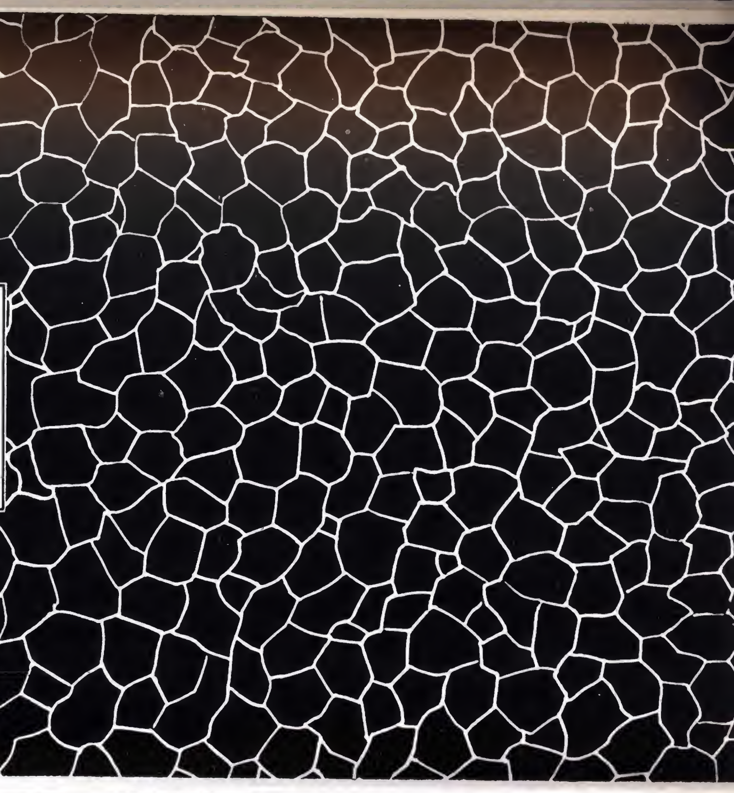


Grain Size No. 3

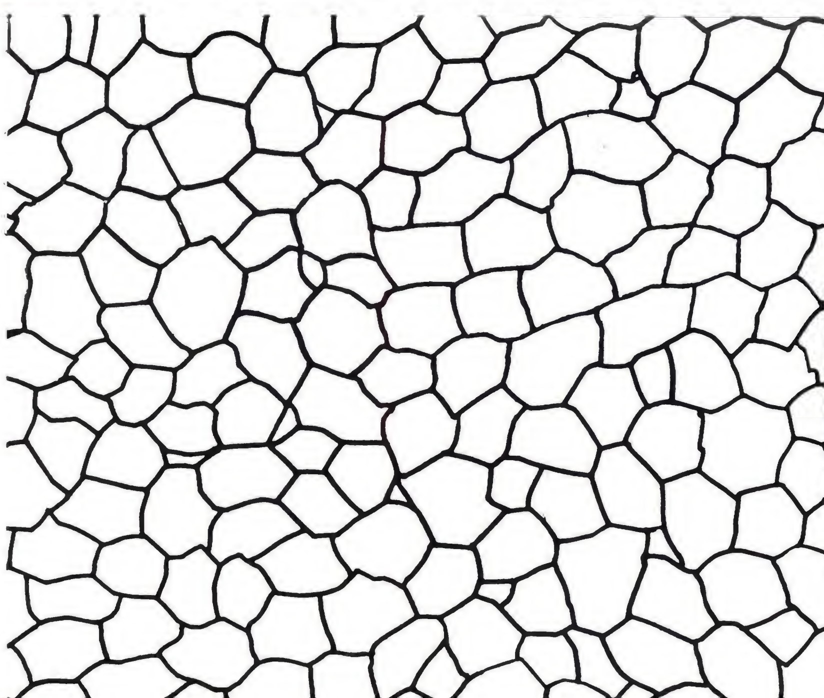
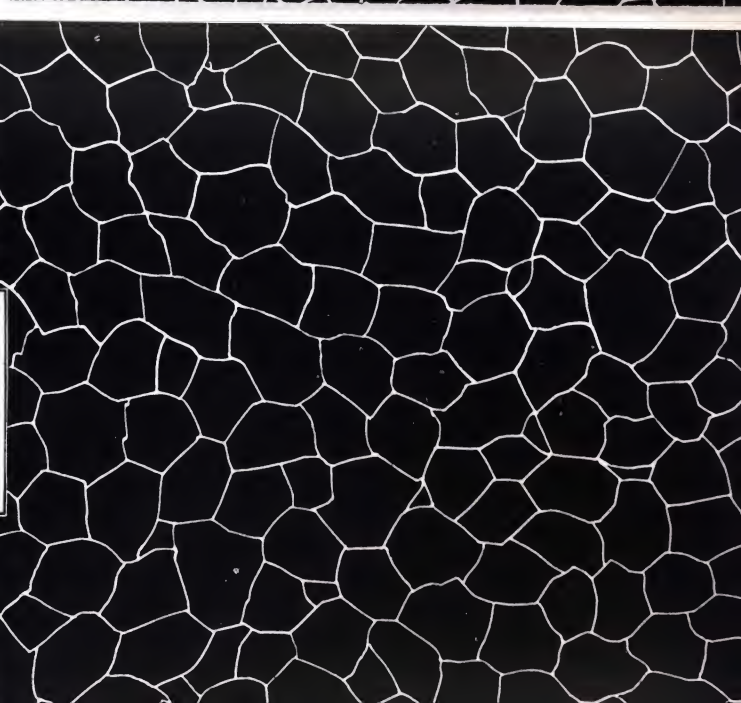


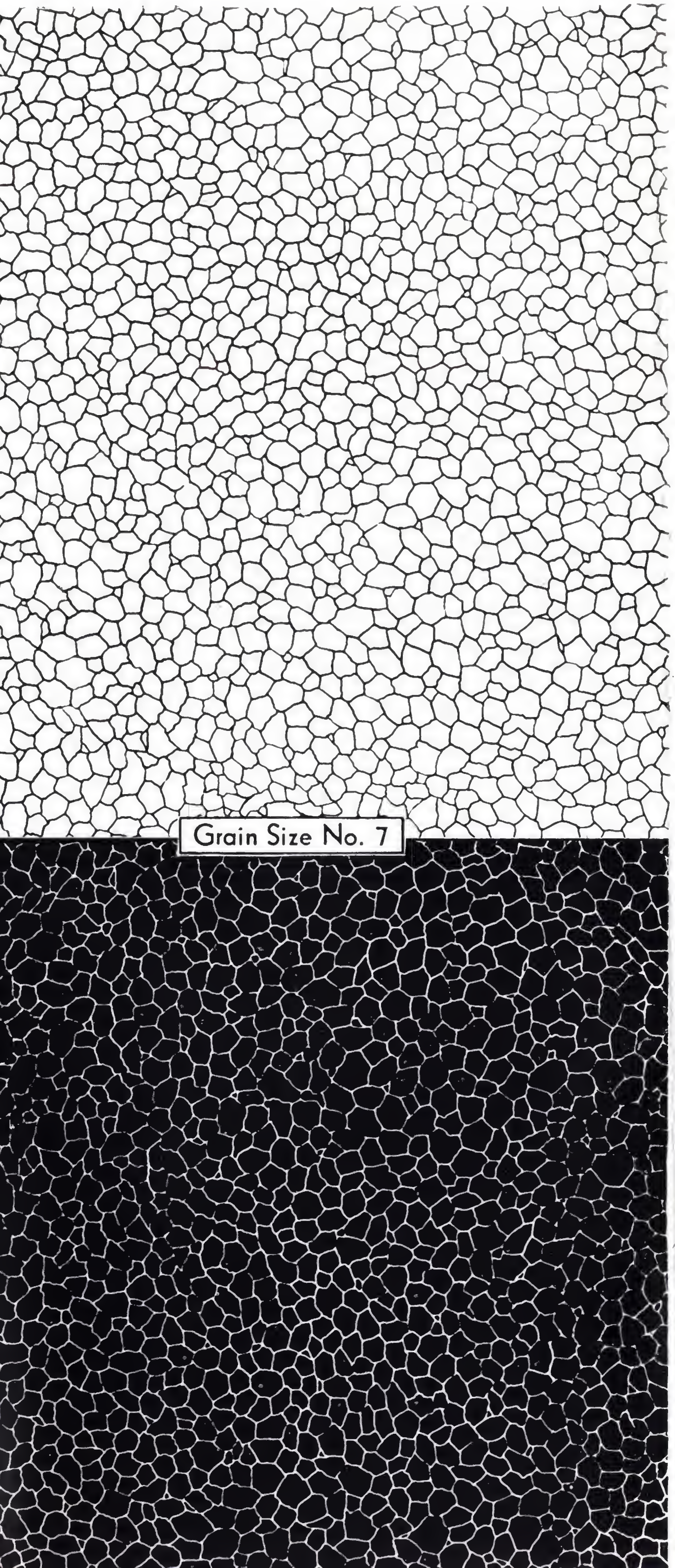
Grain Size No. 6

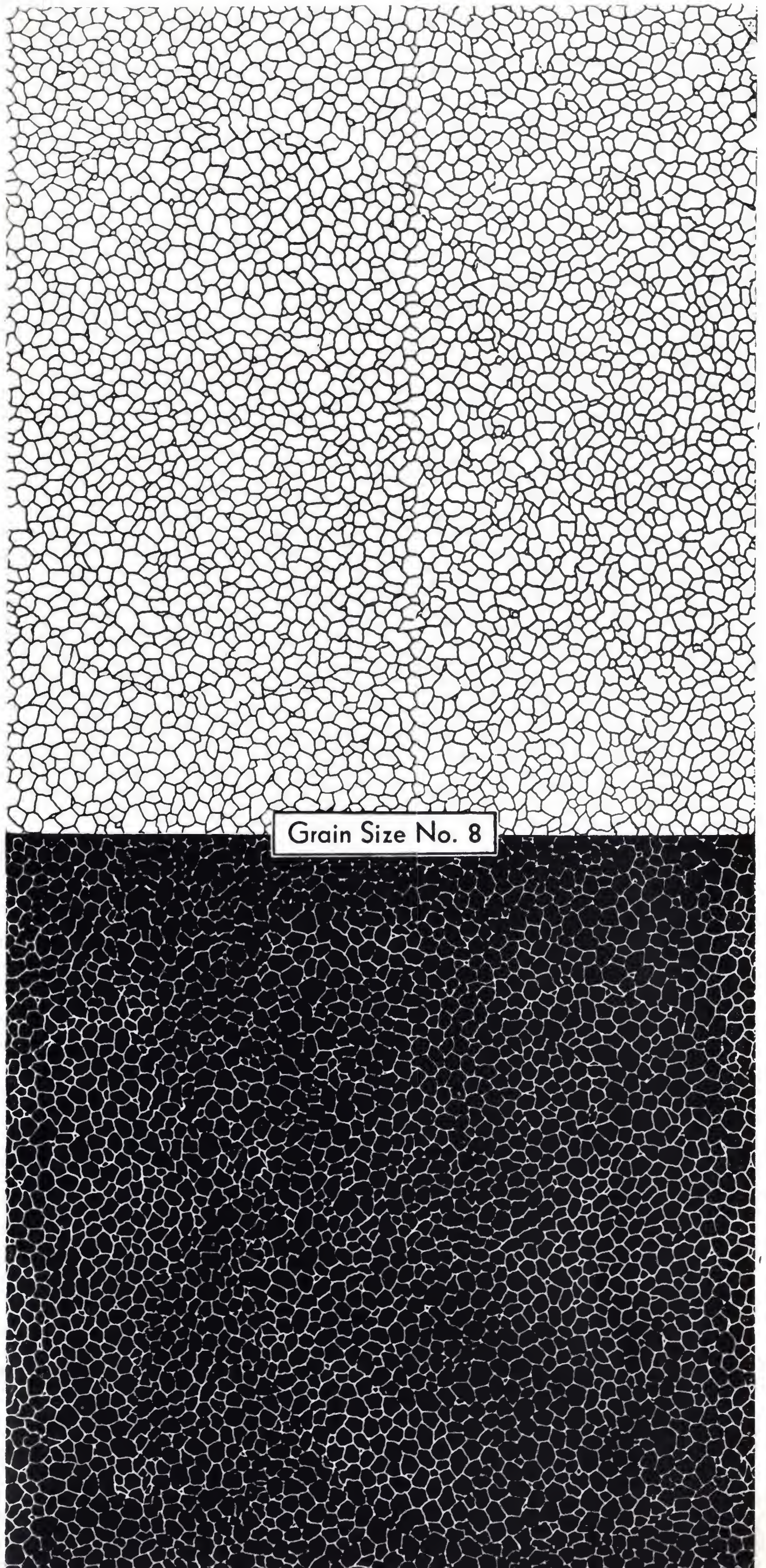
Grain Size No. 5

Grain Size No. 4



Grain Size No. 7



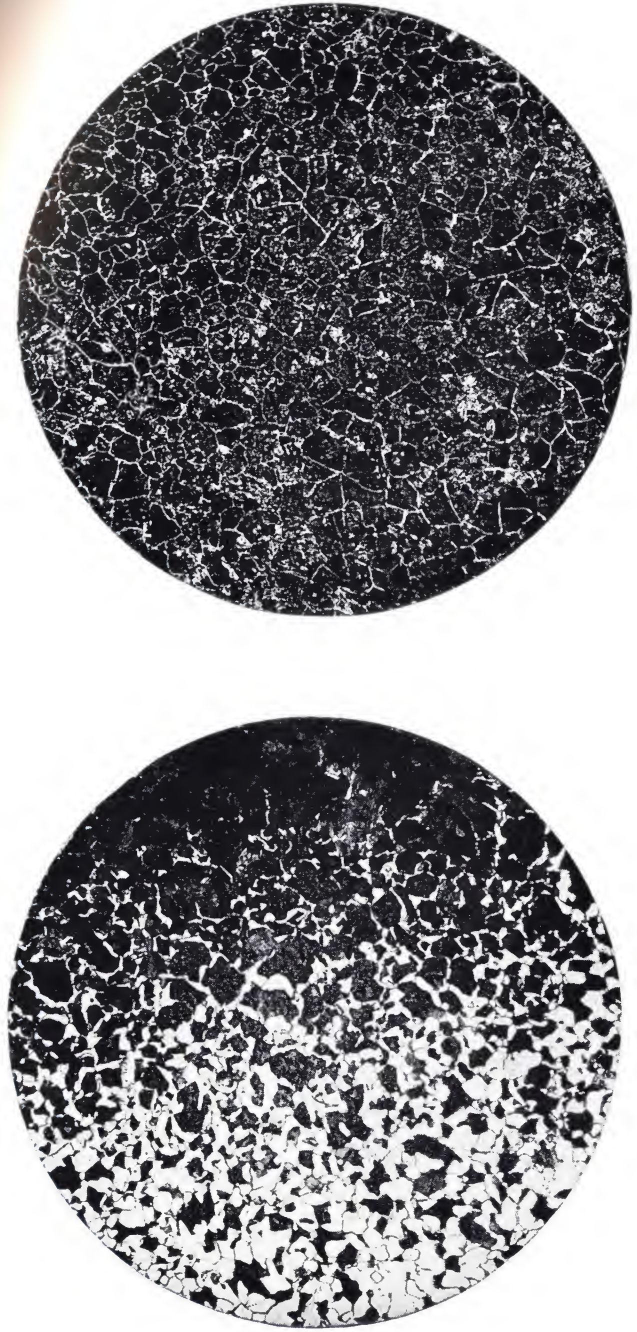
Grain Size No. 8

PLATE II
1942 A.S.T.M. STANDARDS, PART 1

GRAIN SIZE CHART
FOR CLASSIFICATION OF STEELS

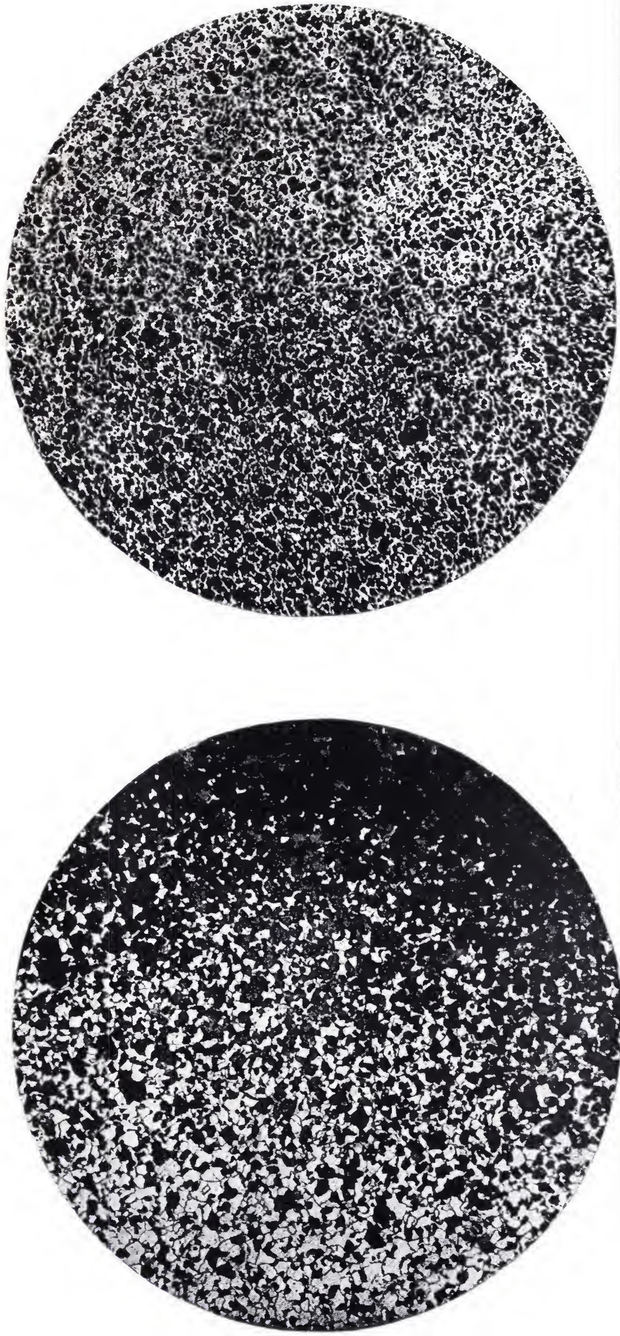
A.S.T.M. DESIGNATION: E 19

No. 6
24 to 48 grains per sq. in.



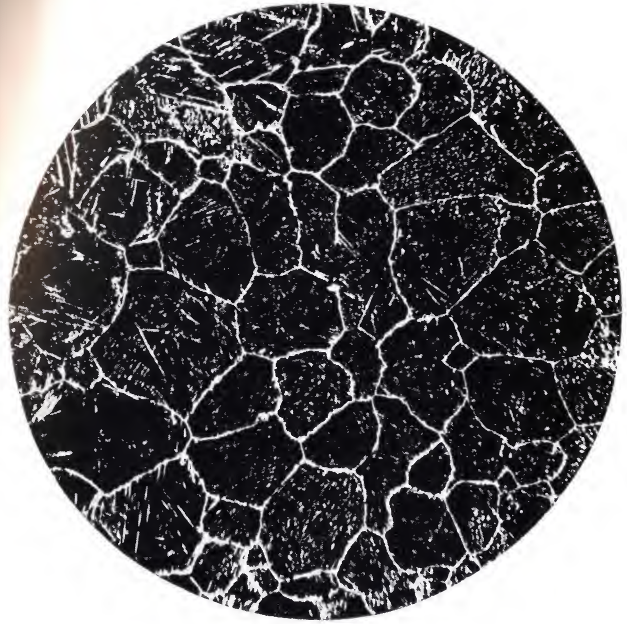
No. 7
48 to 96 grains per sq. in.

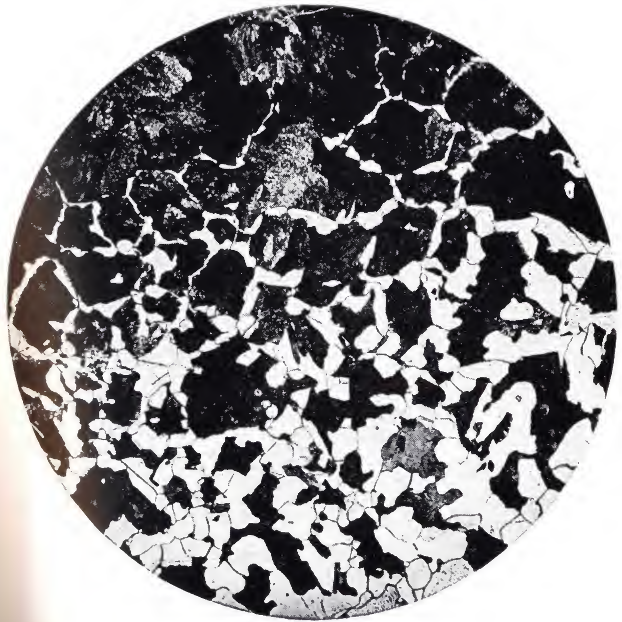
No. 8
96 grains and more per sq. in.



No. 3

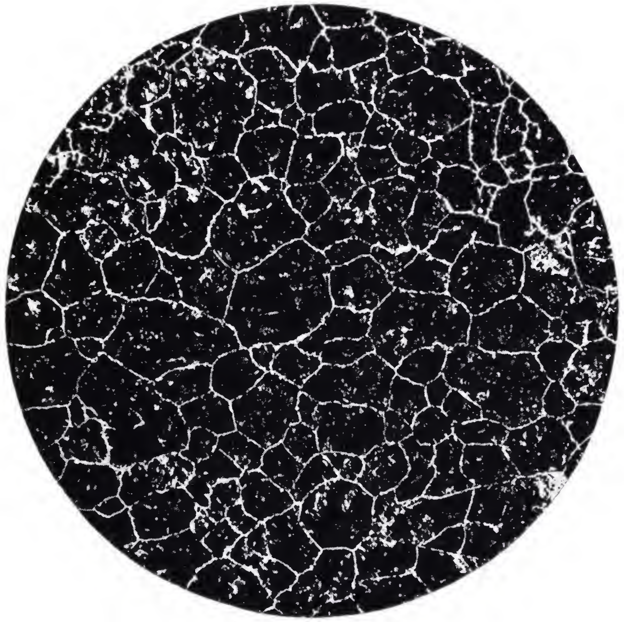
3 to 6 grains per sq. in.





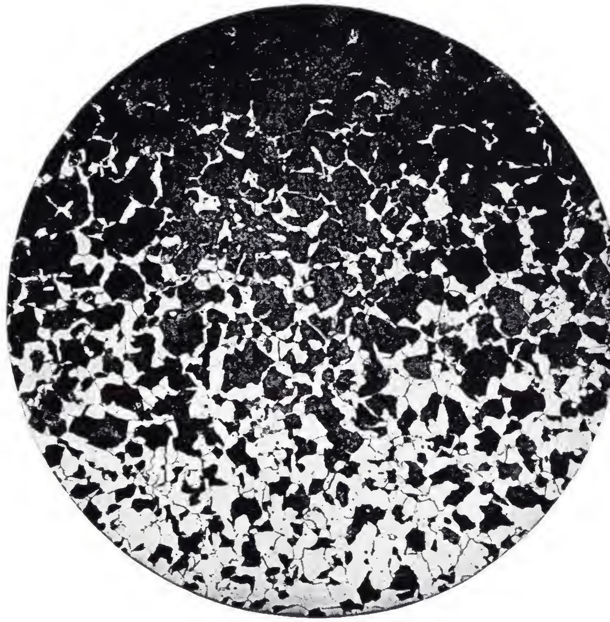
No. 4

6 to 12 grains per sq. in.



No. 5

12 to 24 grains per sq. in.



Grain Size Chart for Classification of Steels (S.A.E. and Allied Structural Steels).

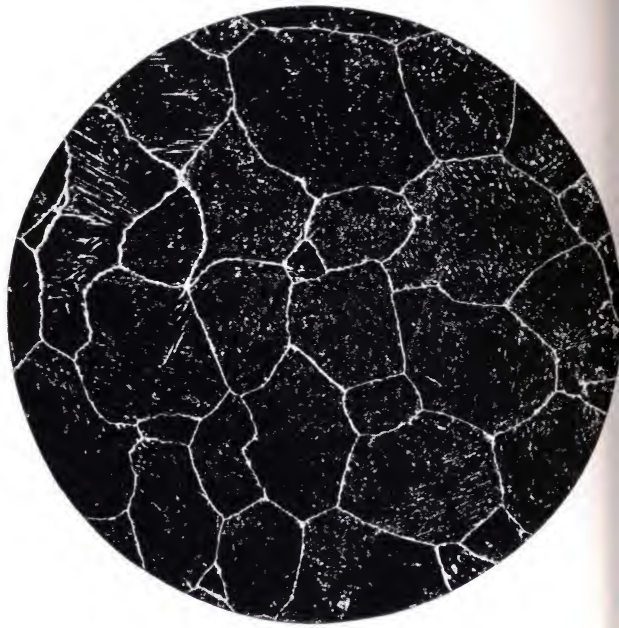
Samples carburized at 1700 F. (927 C.) for 8 hr. (× 100). Upper and lower photomicrographs refer to hypereutectoid and hypo-eutectoid zones, respectively, of the case

No. 1

Up to 1½ grains per sq. in.

No. 2

1½ to 3 grains per sq. in.



PHYSICAL PROPERTIES OF STEELS

Charts (Average Values) appear on the following pages

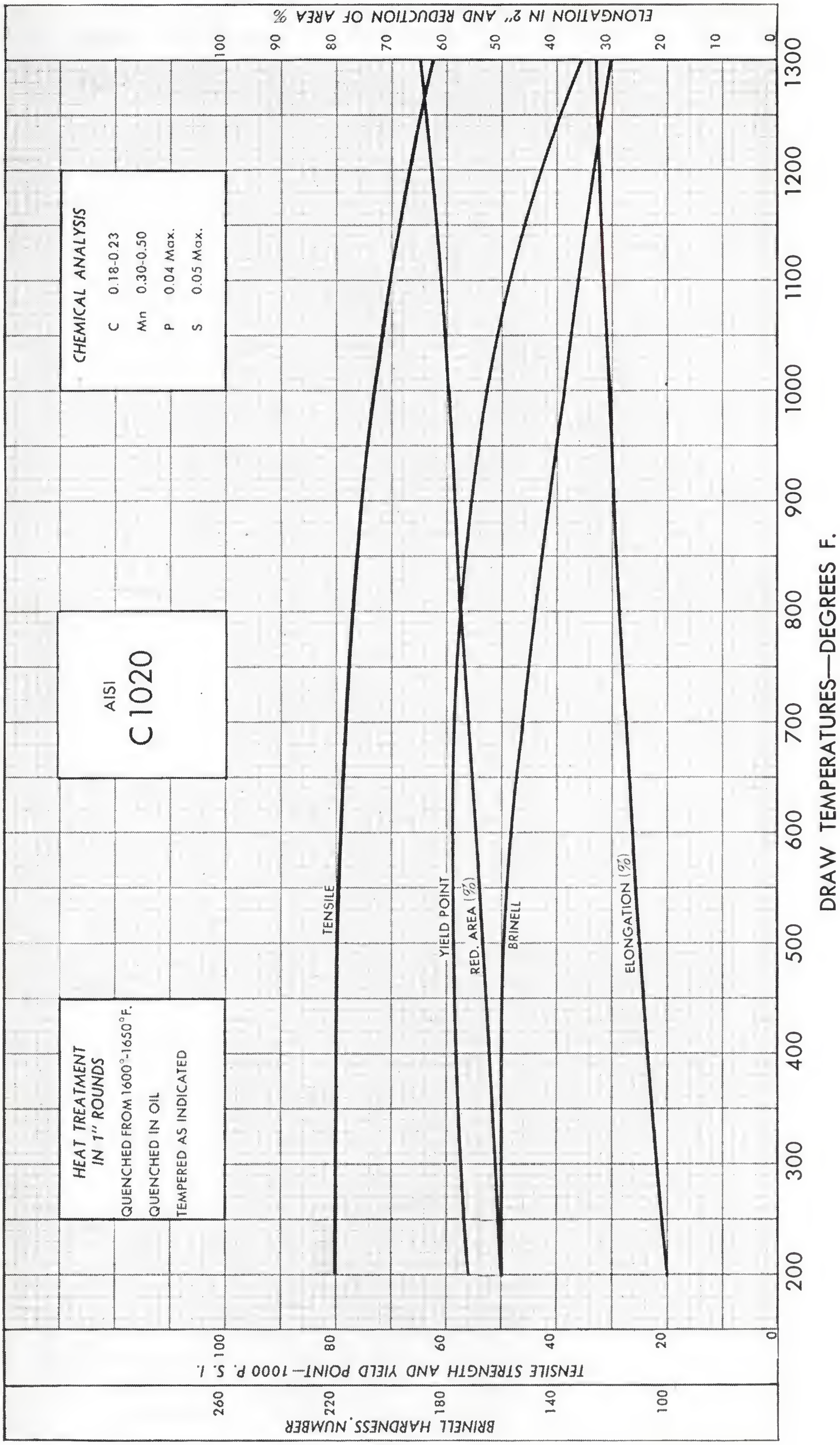
The charts which are represented on the following pages contain representative physical properties obtained on hardened carbon and alloy steels tempered at different temperatures. In the preparation of these charts a large amount of data was examined so as to secure average values for each steel. Variations from the recorded properties will be encountered in practice and higher or lower tempering temperatures than those indicated may be required after hardening to secure given yield points or tensile strengths. These variations arise from a number of causes which may be grouped under three main headings as follows:

1. A range of chemical composition must be allowed for the commercial production of steel of any given type; under given heat treatments those limits which contain carbon, manganese, and alloy contents near the full limit of the range will in general show somewhat higher yield points and strength, and hardness, and low ductility than those steels which contain carbon, manganese, and alloy contents near the low limits. Difference in properties will also be observed from melt to melt in steels of practically the same carbon and alloy contents when procured from the same or different sources.

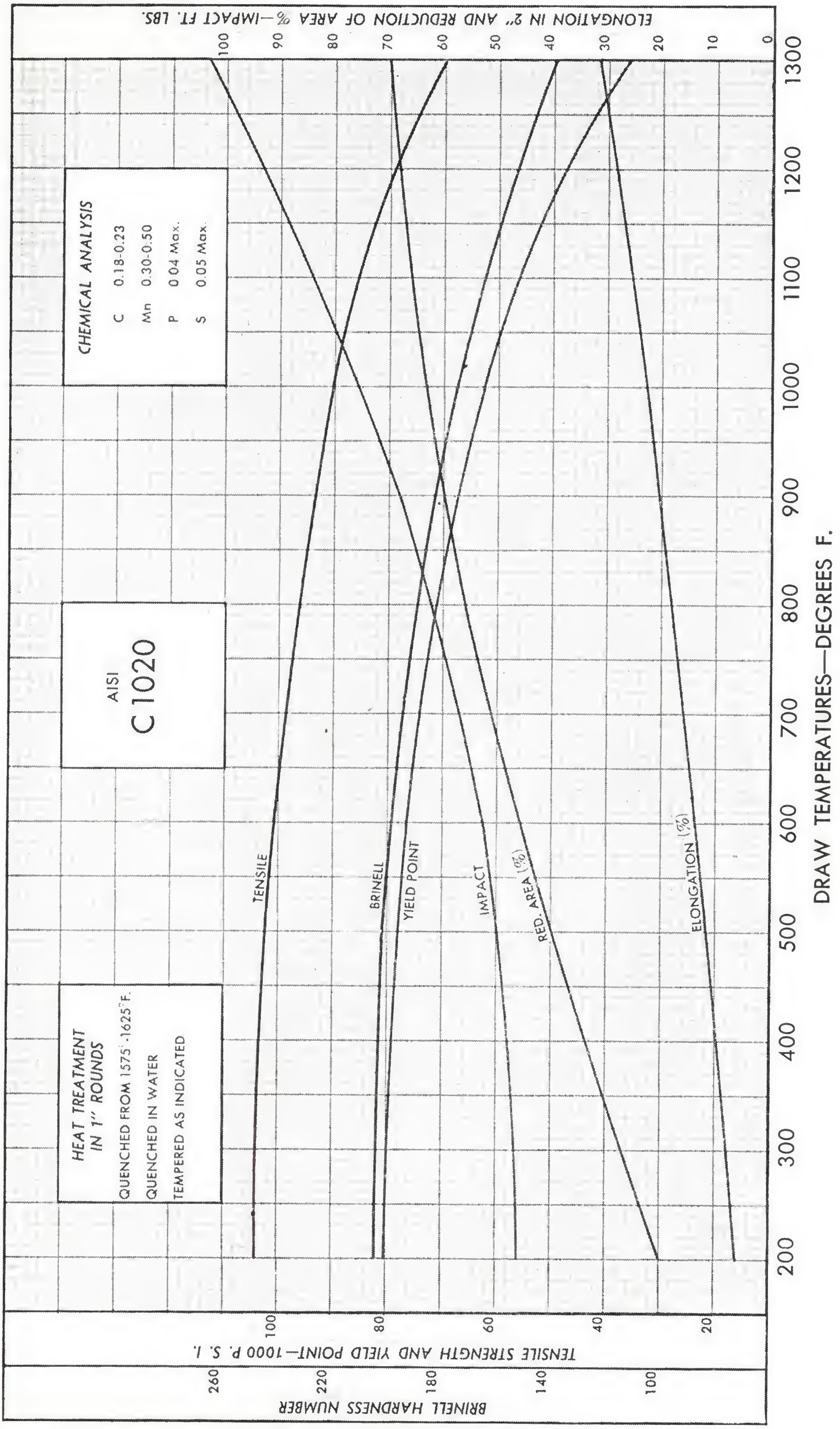
2. The size and shape of a piece when heat treated may make an appreciable difference in the properties produced by given heat treatments. In general, increase in size reduces the rates of cooling, decreases the hardening effects, and results in somewhat reduced mechanical properties, but these effects vary in magnitude in the different classes of steel. Parts heat treated in finished standard test piece size will generally show higher hardness, yield points and strengths and longer elongation and reductions of area than pieces quenched in larger sections and machined after the same heat treatments.

3. Other variables are encountered in the heat treatment of steels which can effect the properties obtained. Among these variables are the temperature and times of heating for quenching, the character of the quenching medium, its temperature and manner of submersion, the condition of the surface of the steel piece when quenched, the time at the tempering temperatures, etc. Variations in the results obtained may also be produced by differences in the methods of test employed, thus skill in testing is required for accurate determination of properties.

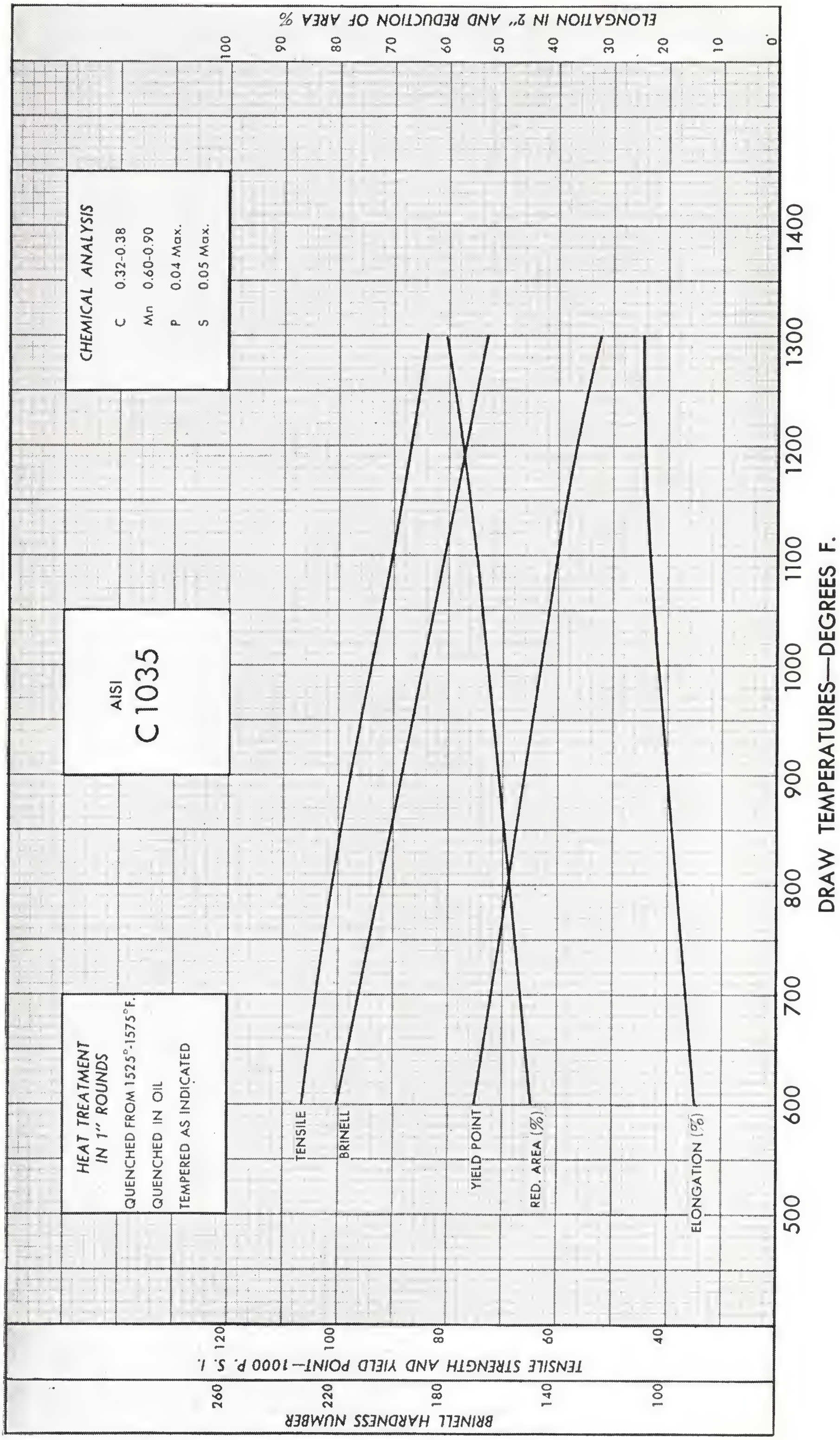
PHYSICAL PROPERTIES CHART (Average Values)
AISI – C1020



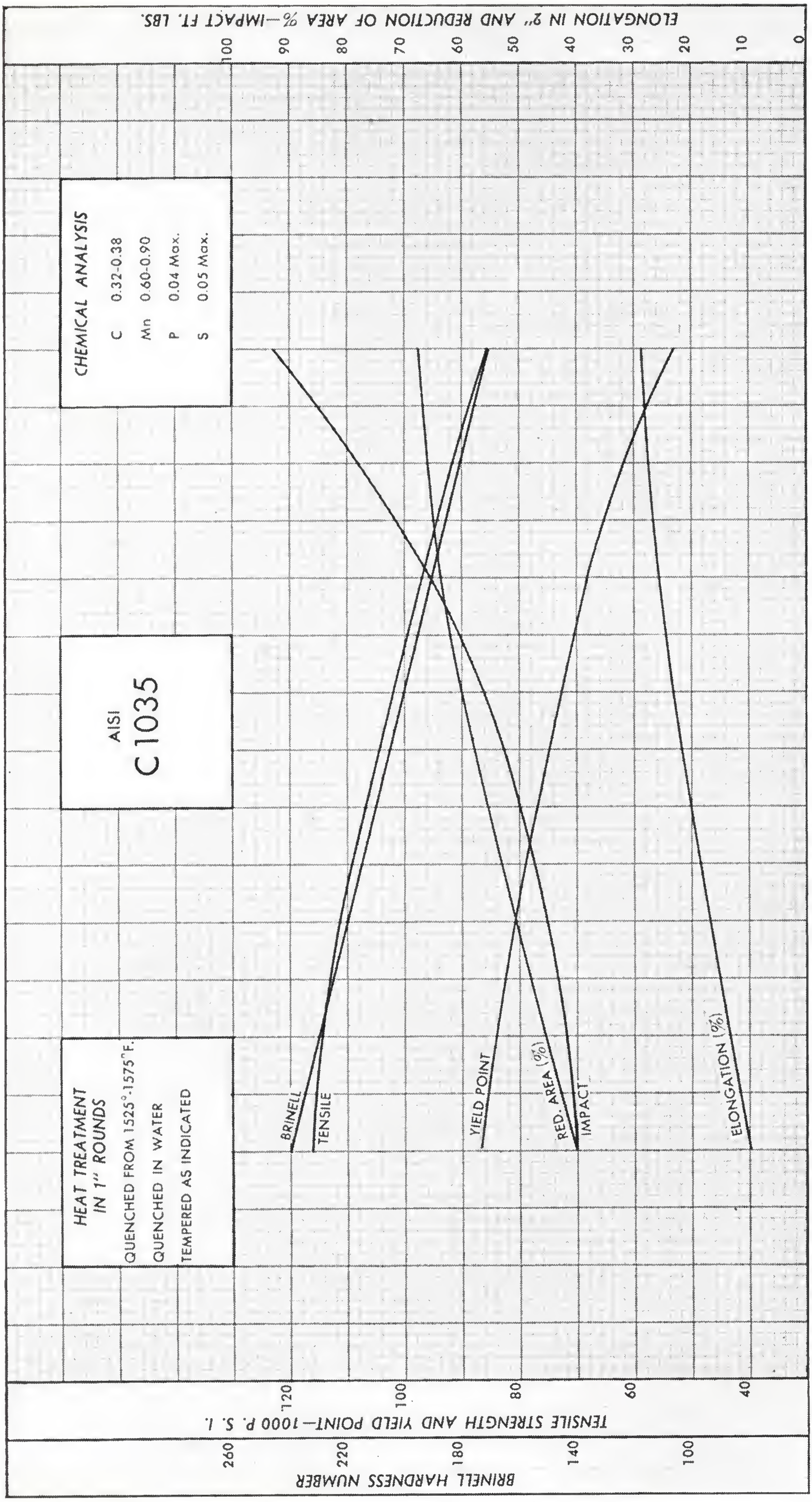
PHYSICAL PROPERTIES CHART (Average Values)
AISI – C1020



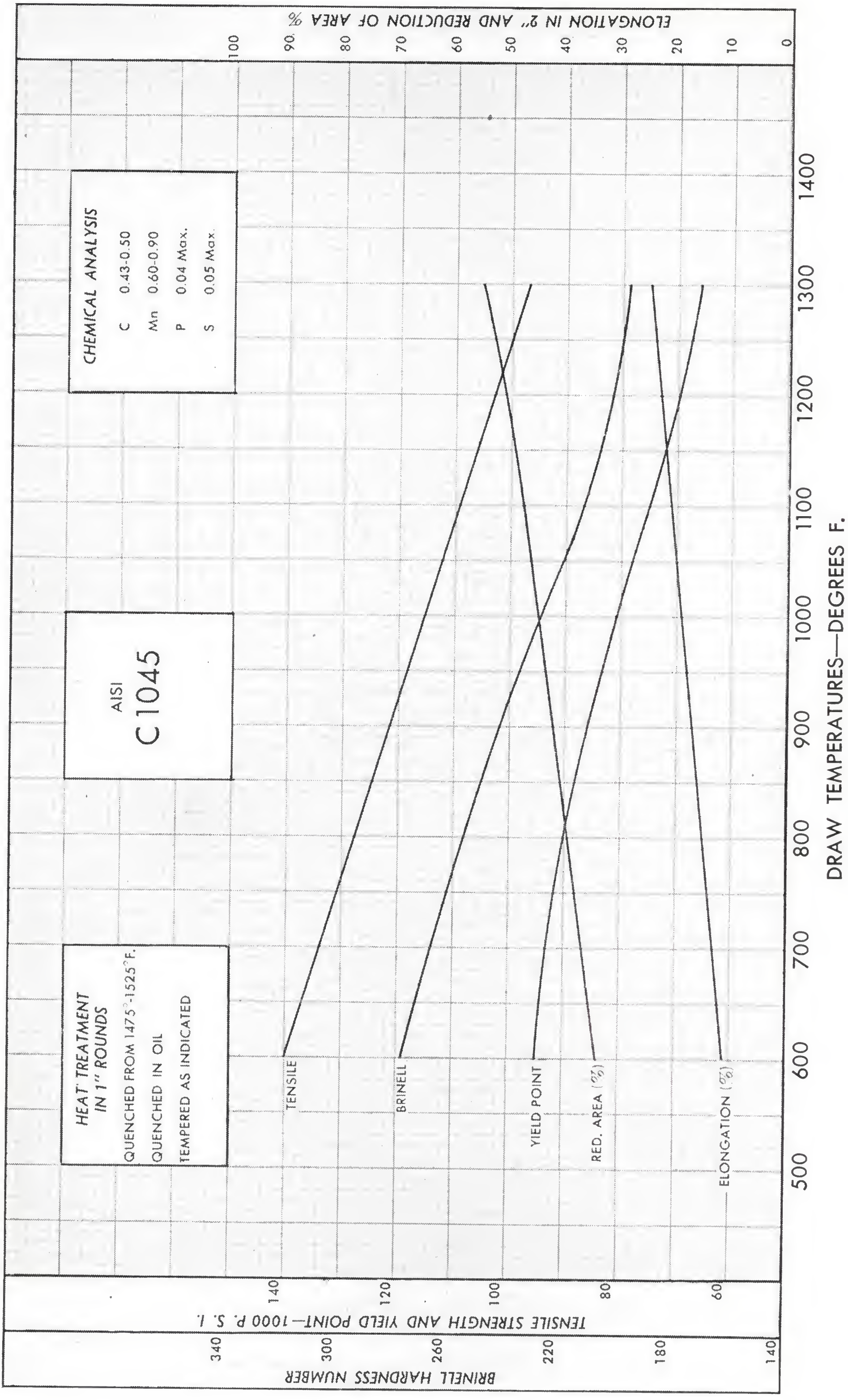
PHYSICAL PROPERTIES CHART (Average Values)
AISI – C1035



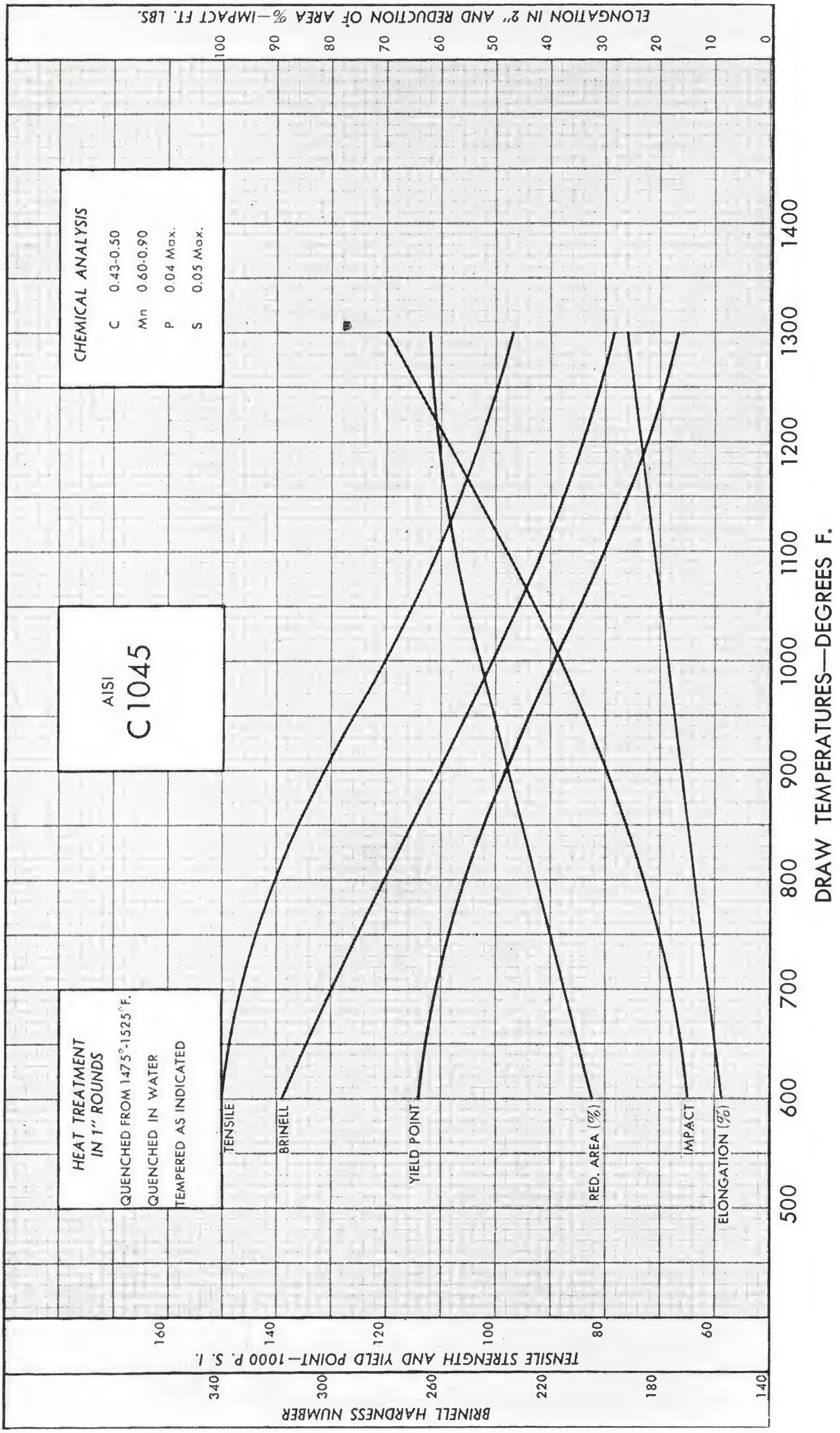
PHYSICAL PROPERTIES CHART (Average Values)
AISI – C1035



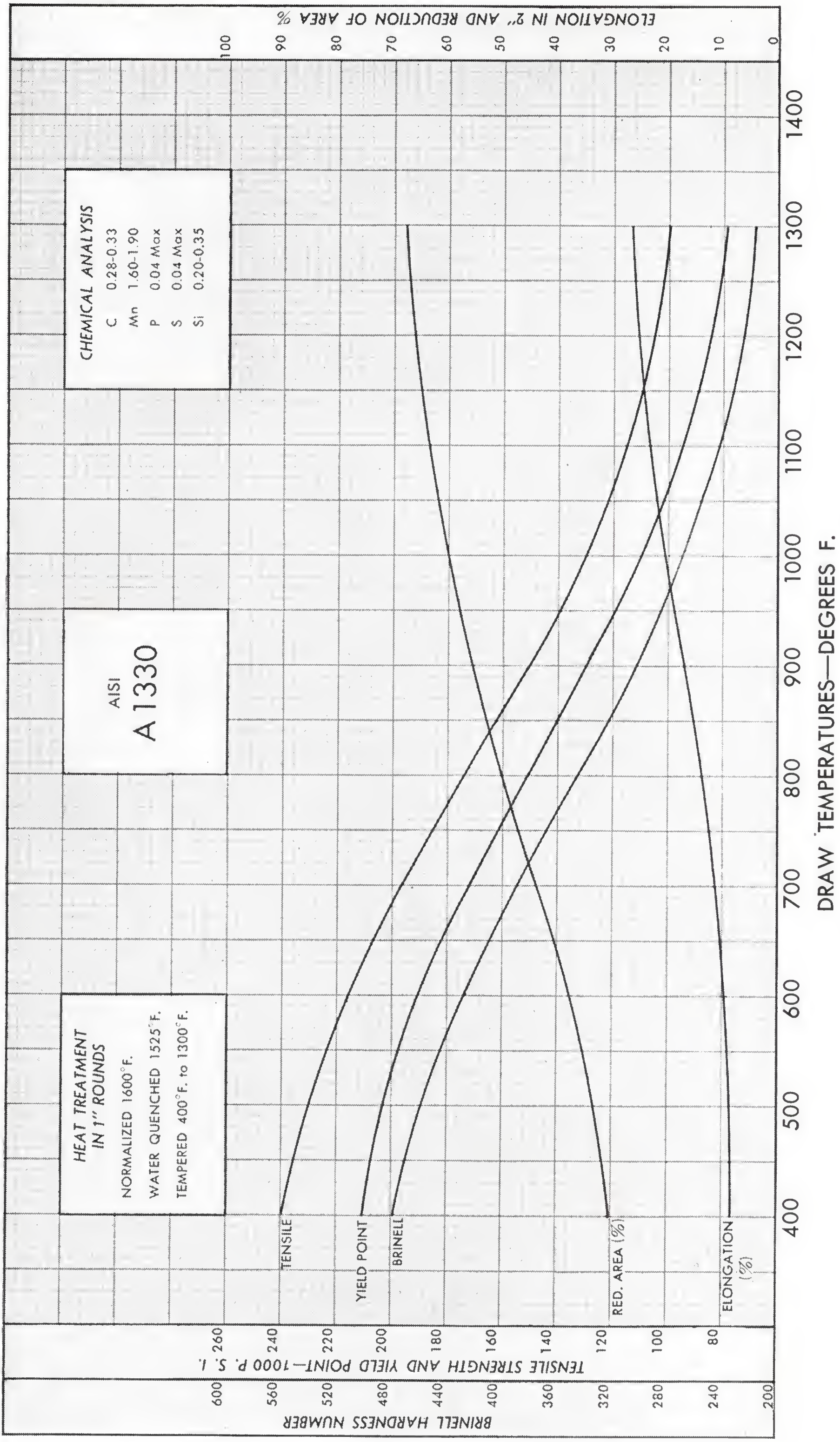
PHYSICAL PROPERTIES CHART (Average Values)
AISI — C1045



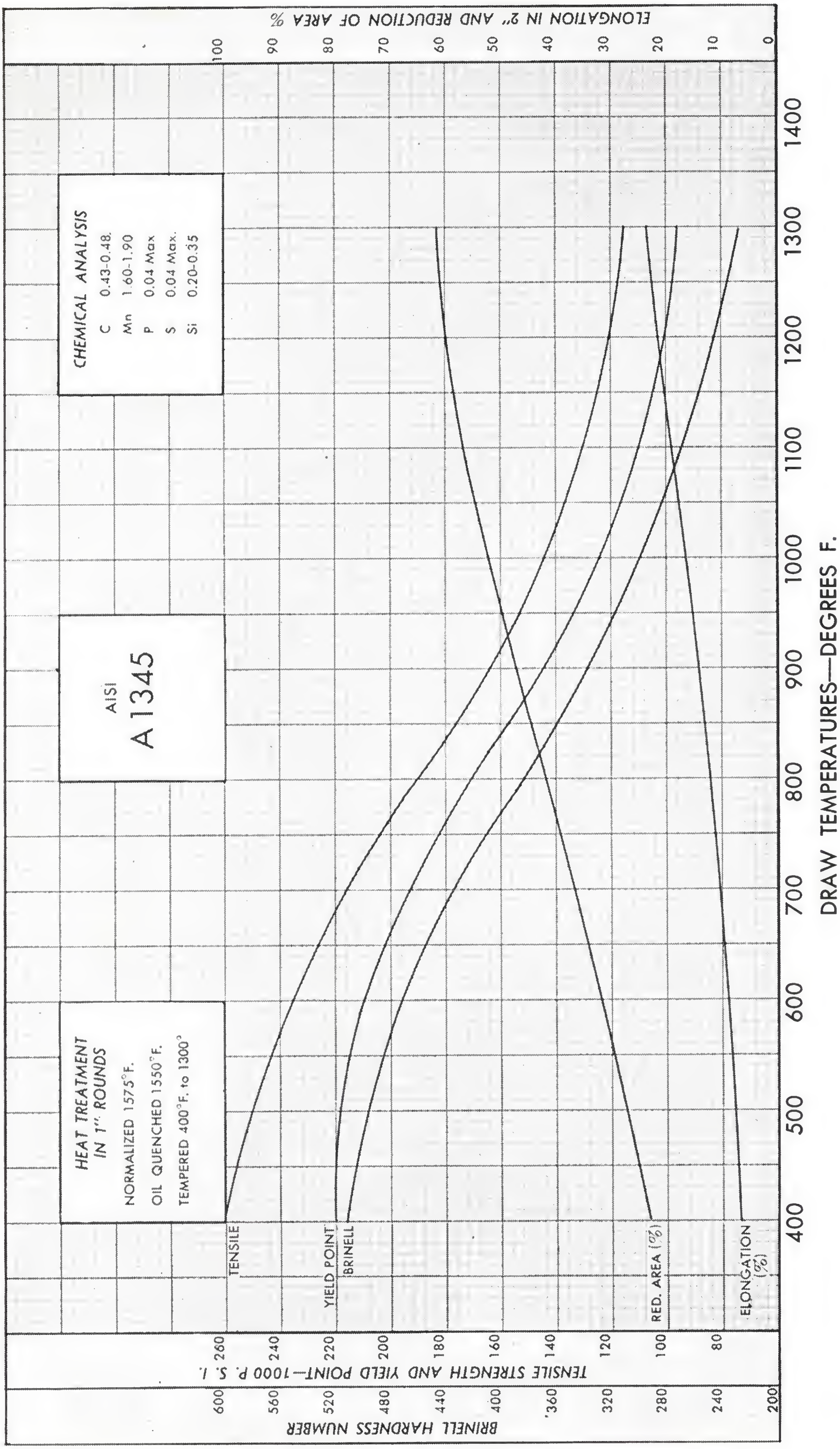
PHYSICAL PROPERTIES CHART (Average Values)
AISI – C1045



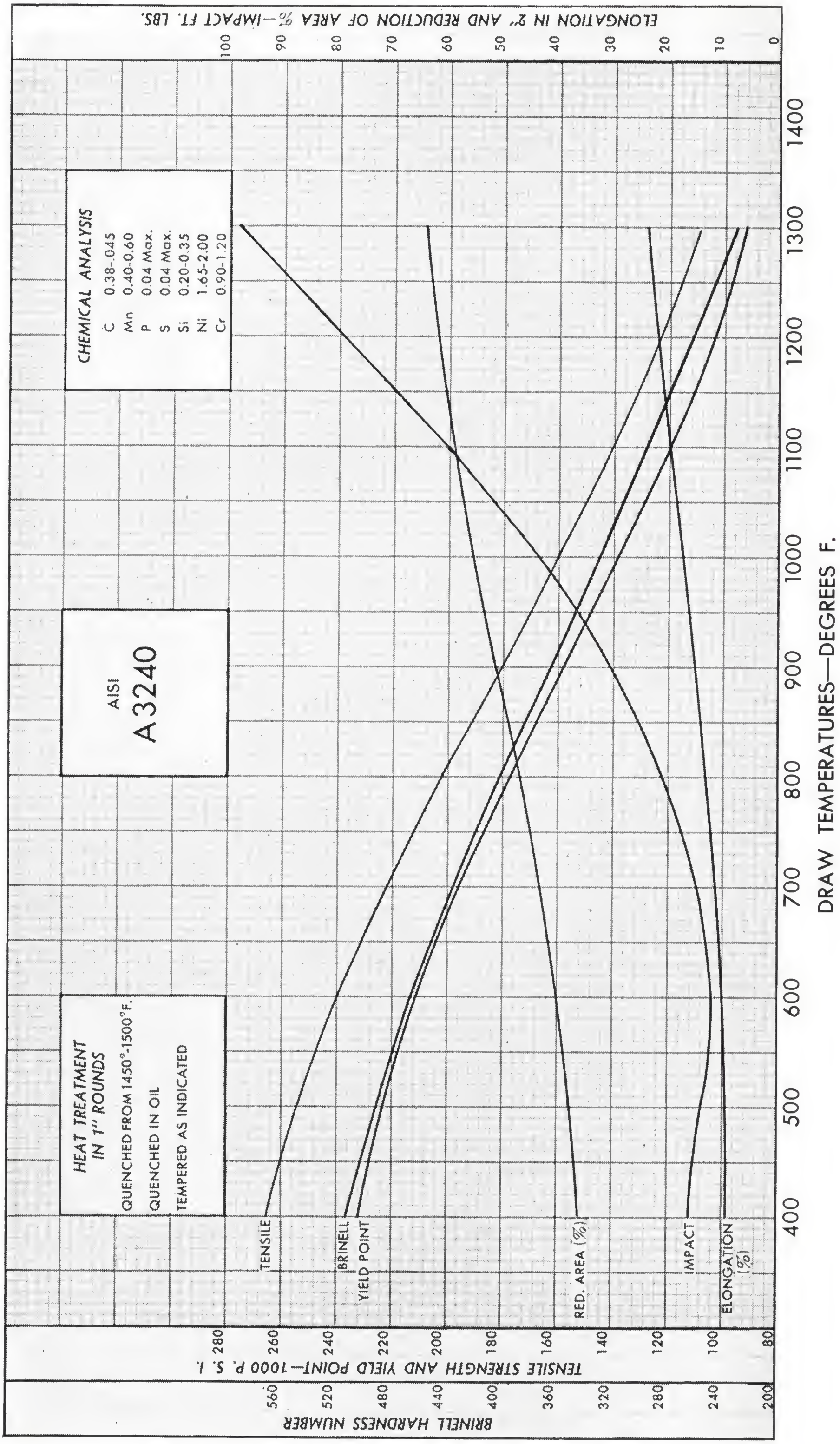
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A1330



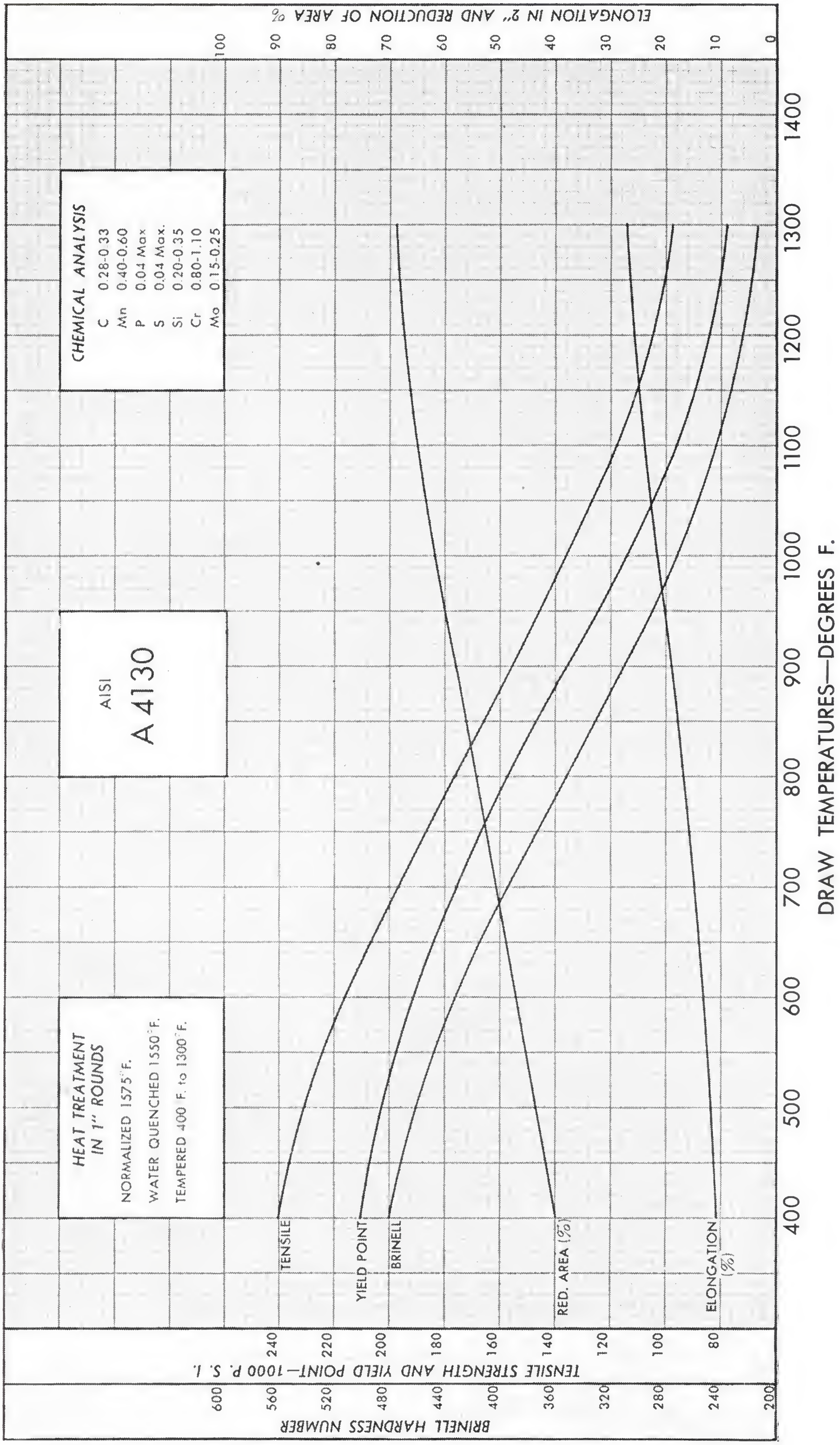
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A1345



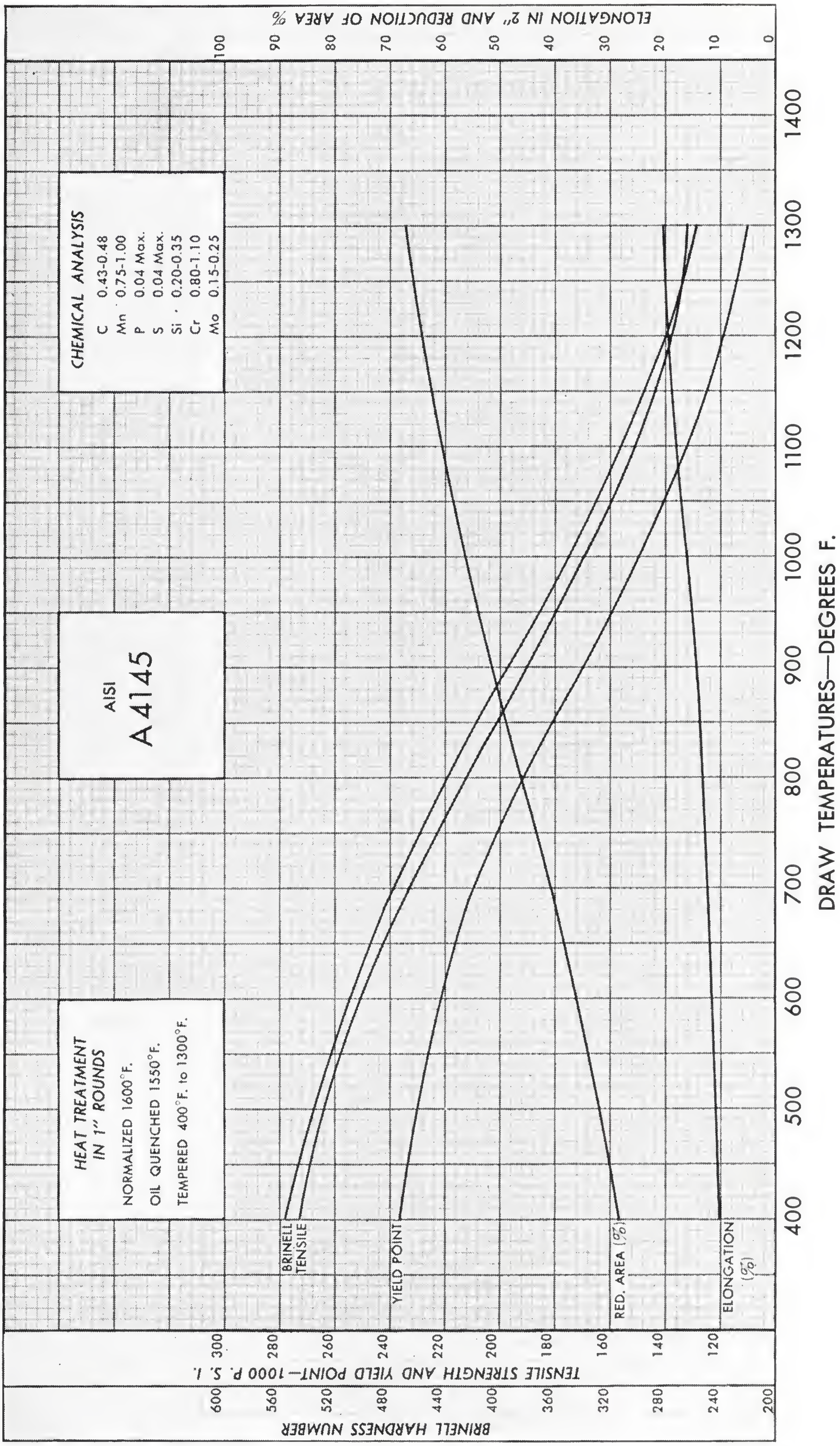
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A3240



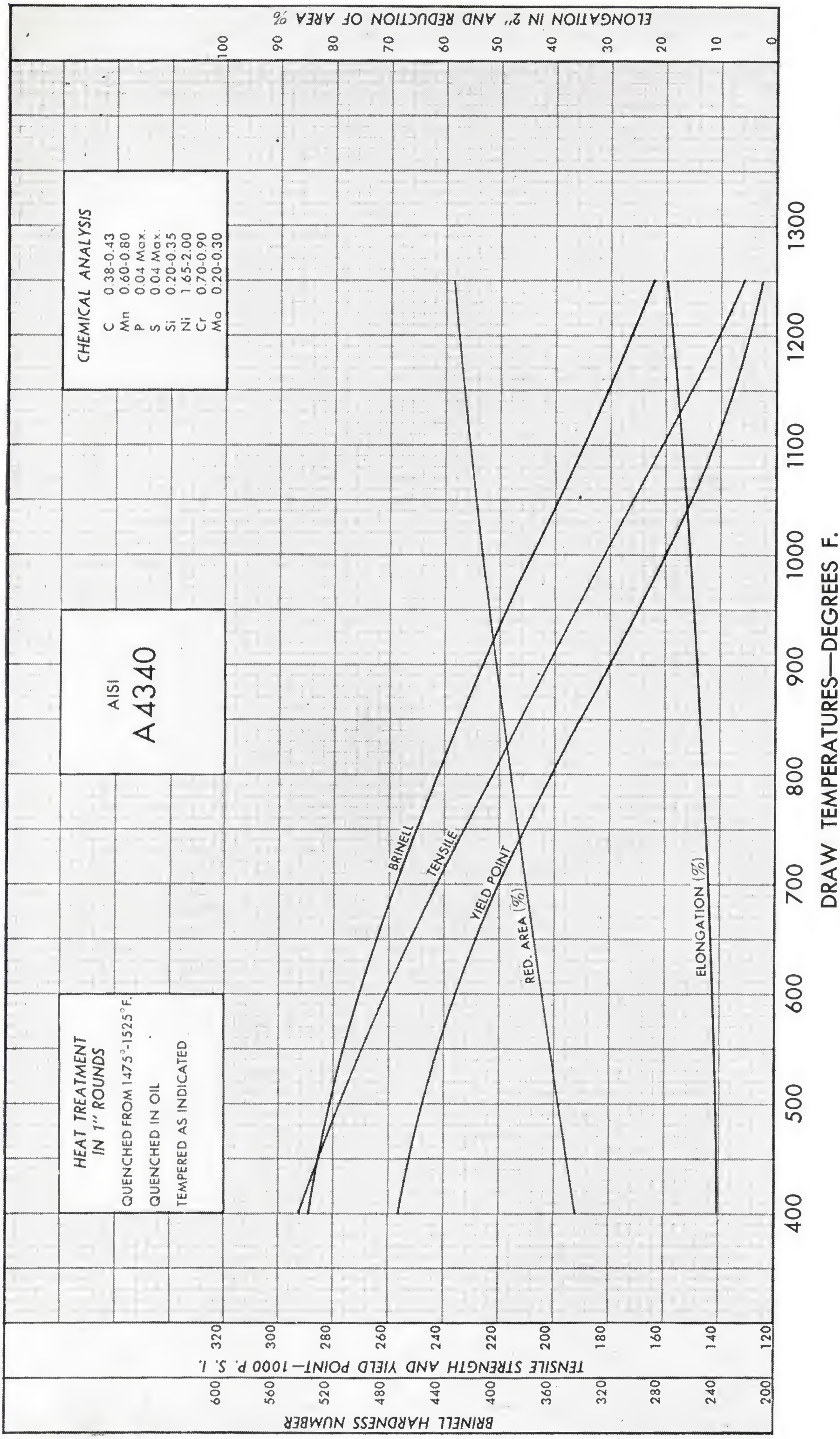
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A4130



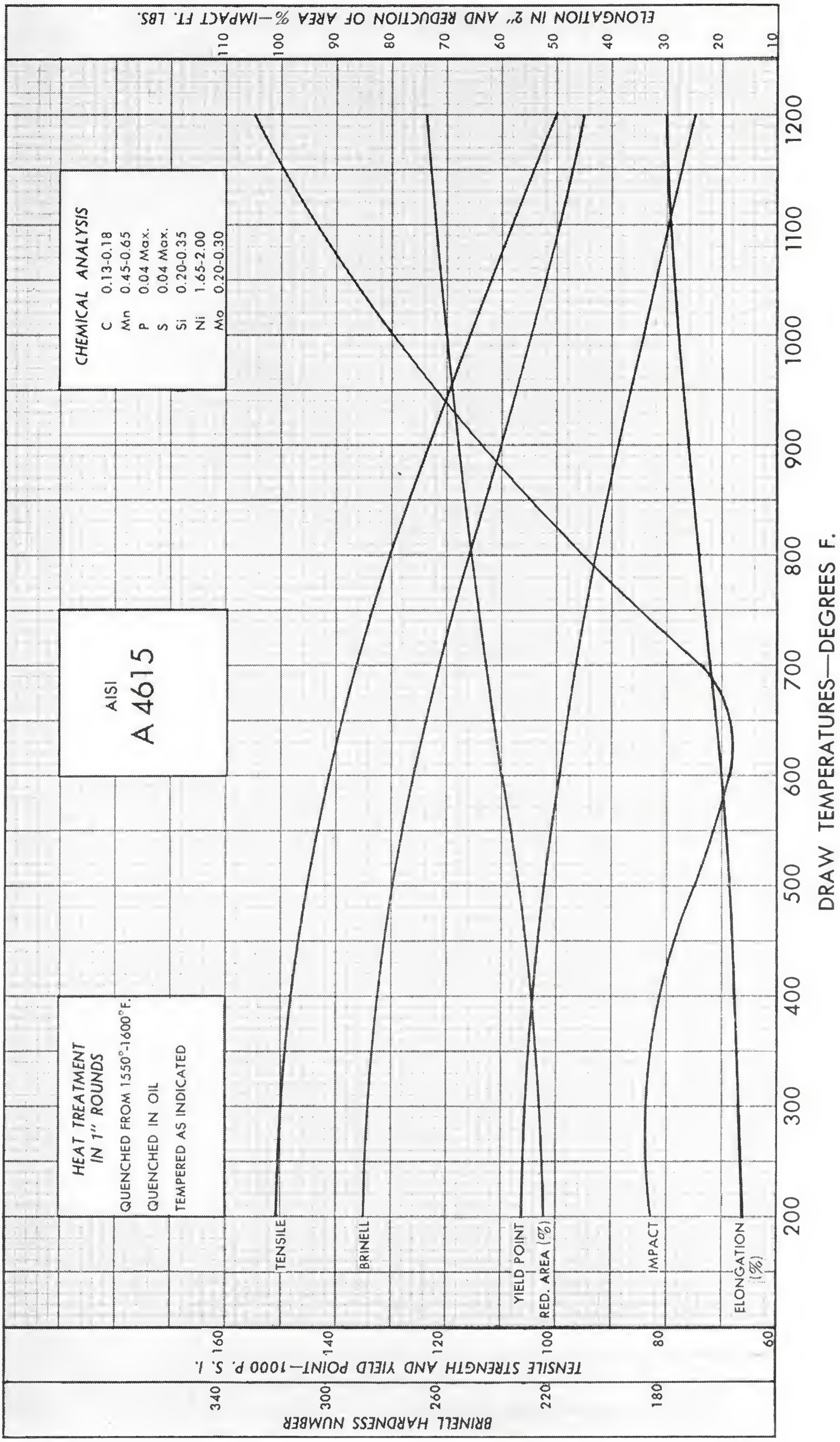
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A4145



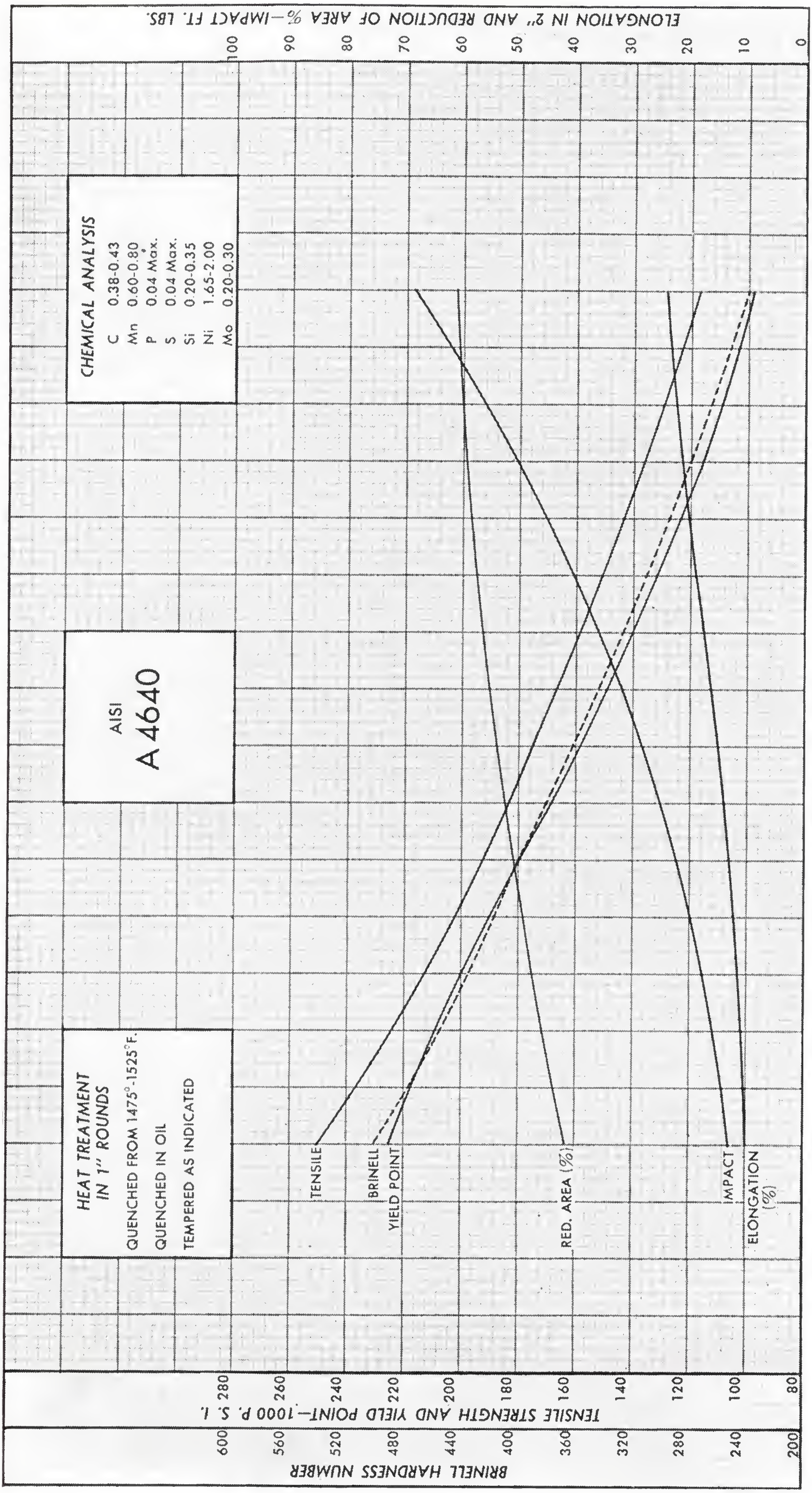
PHYSICAL PROPERTIES CHART (Average Values)
AISI — A4340



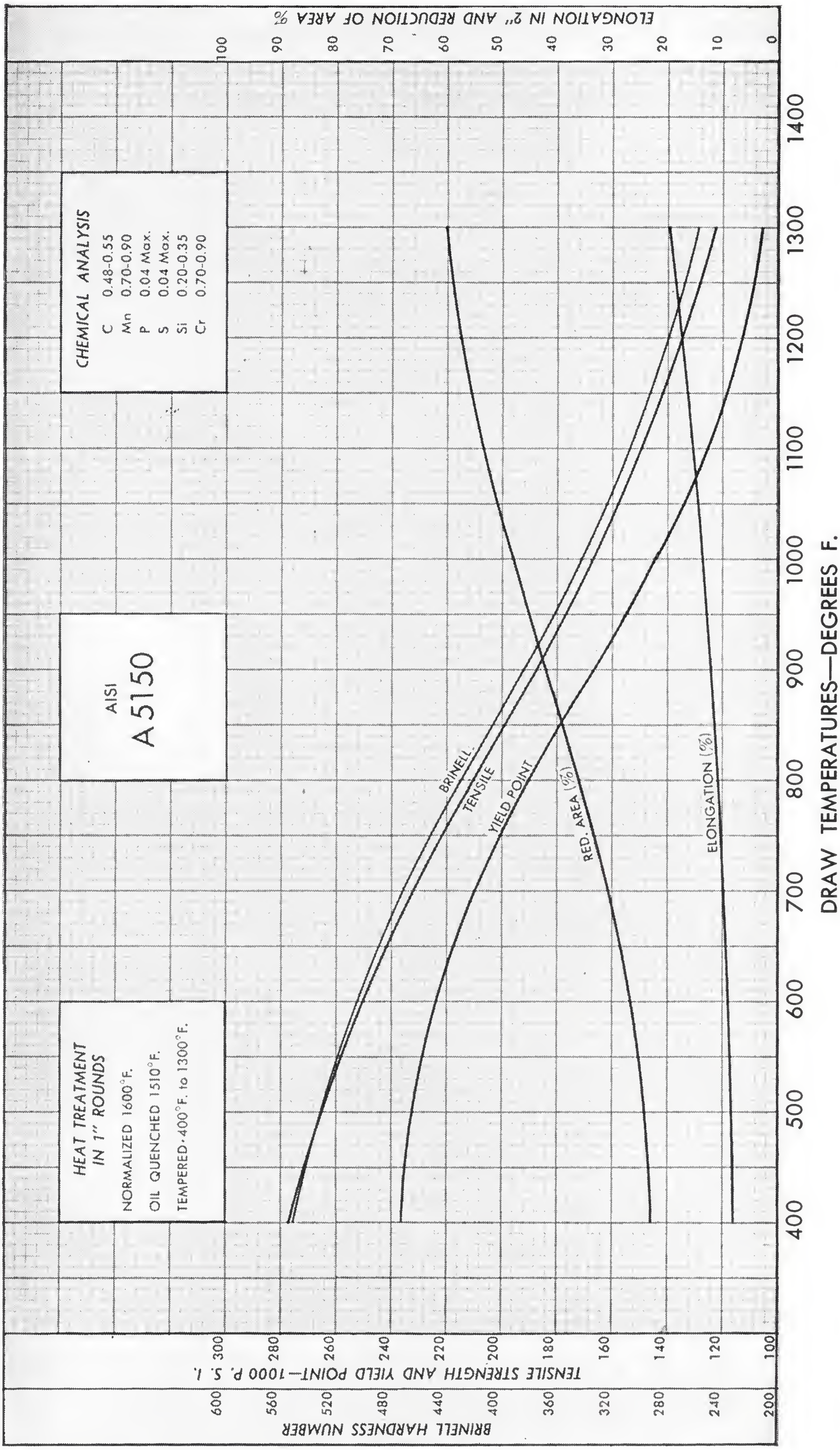
PHYSICAL PROPERTIES CHART (Average Values)
AISI—A4615



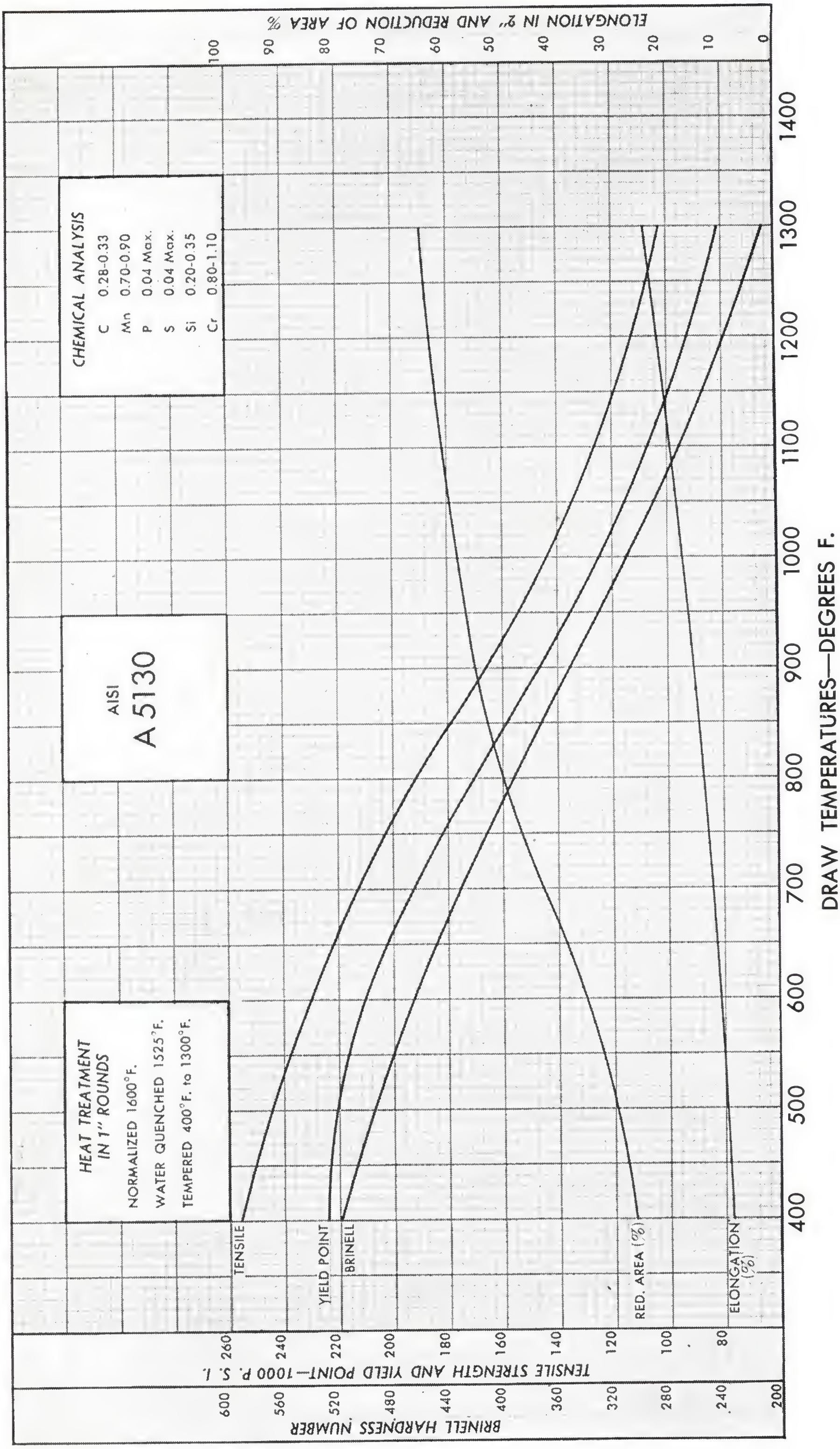
PHYSICAL PROPERTIES CHART (Average Values)
AISI – A4640



PHYSICAL PROPERTIES CHART (Average Values)
AISI – A5150



PHYSICAL PROPERTIES CHART (Average Values)
AISI – A5130



PHYSICAL PROPERTIES CHART (Average Values)
N. E. 8630

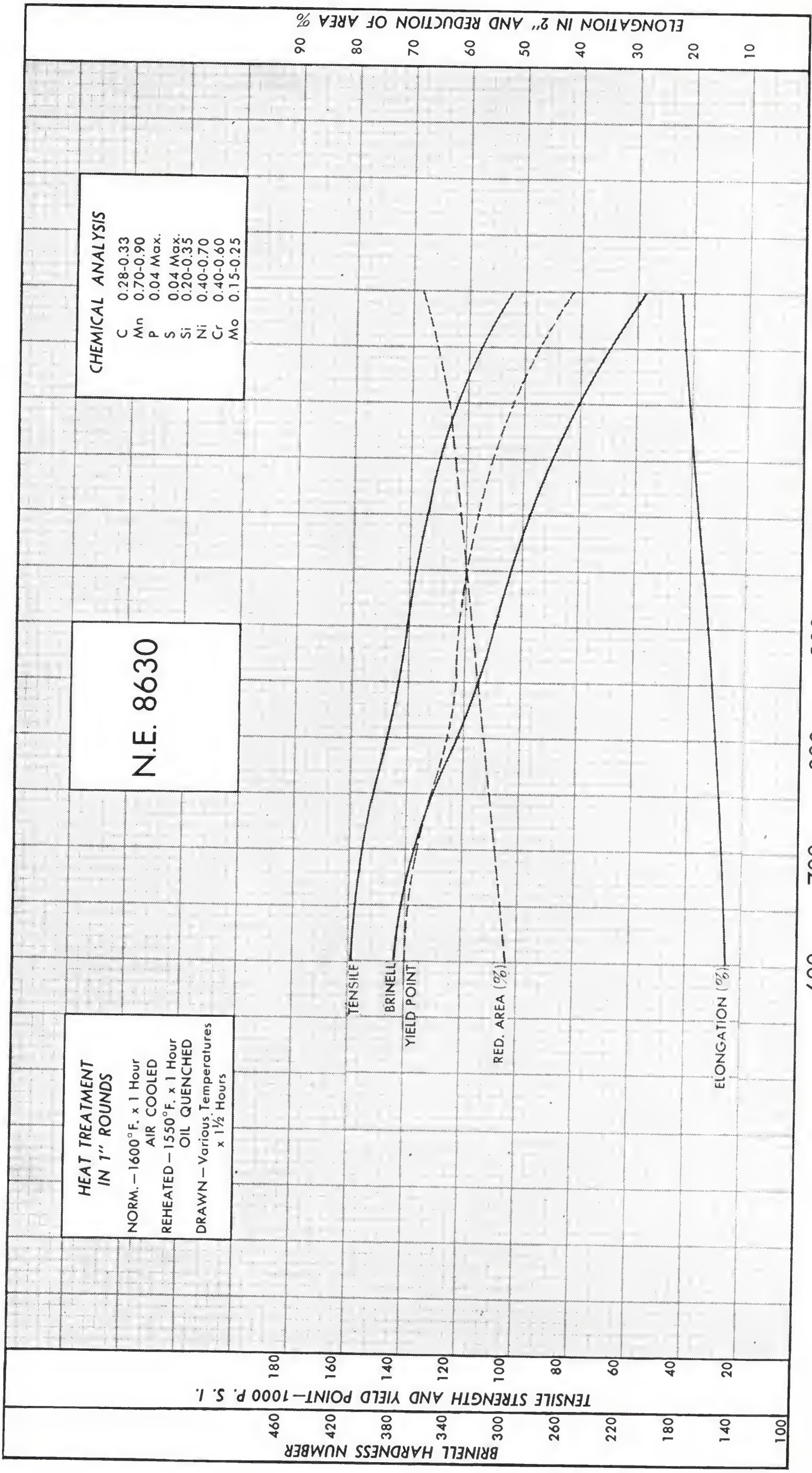


TABLE OF GAUGES

No. of Wire Gauge	Pittsburgh Steel Co. or Washburn & Moen	Birmingham or Stubb's	Brown & Sharpe	British Imperial or English Legal Standard	United States Standard Gage U.S.S.G. Uncoated Steel Sheets and Light Plates: Equivalent Thickness Inch	Lb. per Sq. Ft.
0000000	.4900	......	....	......	.4902	20.0000
000000	.4615	......	....	.464	.4596	18.7500
00000	.4305	......	....	.432	.4289	17.5000
0000	.3938	.454	.46000	.400	.3983	16.2500
000	.3625	.425	.40964	.372	.3676	15.0000
00	.3310	.380	.36480	.348	.3370	13.7500
0	.3065	.340	.32495	.324	.3064	12.5000
1	.2830	.300	.28930	.300	.2757	11.2500
2	.2625	.284	.25763	.276	.2604	10.6250
3	.2437	.259	.22942	.252	.2451	10.0000
4	.2253	.238	.20431	.232	.2298	9.3750
5	.2070	.220	.18194	.212	.2145	8.7500
6	.1920	.203	.16202	.192	.1991	8.1250
7	.1770	.180	.14428	.176	.1838	7.5000
8	.1620	.165	.12849	.160	.1685	6.8750
9	.1483	.148	.11443	.144	.1532	6.2500
10	.1350	.134	.10189	.128	.1379	5.6250
11	.1201	.120	.09074	.116	.1225	5.0000
12	.1055	.109	.08081	.104	.1072	4.3750
13	.0915	.095	.07196	.092	.0919	3.7500
14	.0800	.083	.06408	.080	.0766	3.1250
15	.0720	.072	.05707	.072	.0689	2.8125
16	.0625	.065	.05082	.064	.0613	2.5000
17	.0540	.058	.04526	.056	.0551	2.2500
18	.0475	.049	.04030	.048	.0490	2.0000
19	.0410	.042	.03589	.040	.0429	1.7500
20	.0348	.035	.03196	.036	.0368	1.5000
21	.0317	.032	.02846	.032	.0337	1.3750
22	.0286	.028	.02535	.028	.0306	1.2500
23	.0258	.025	.02257	.024	.0276	1.1250
24	.0230	.022	.02010	.022	.0245	1.0000
25	.0204	.020	.01790	.020	.0214	.8750
26	.0181	.018	.01594	.018	.0184	.7500
27	.0173	.016	.01419	.0164	.0169	.6875
28	.0162	.014	.01264	.0148	.0153	.6250
29	.0150	.013	.01126	.0136	.0138	.5625
30	.0140	.012	.01002	.0124	.0123	.5000
31	.0132	.010	.00893	.0116	.0107	.4375
32	.0128	.009	.00795	.0108	.0100	.4062
33	.0118	.008	.00708	.0100	.0092	.3750
34	.0104	.007	.00630	.0092	.0084	.3437
35	.0095	.005	.00561	.0084	.0077	.3125
36	.0090	.004	.00500	.0076	.0069	.2812
37	.0085	......	.00445	.0068	.0065	.2656
38	.0080	......	.00396	.0060	.0061	.2500
39	.0075	......	.00353	.0052	.0057	.2344
40	.0070	......	.00314	.0048	.0054	.2187

BRINELL HARDNESS NUMBERS

The Brinell hardness number is calculated from the formula as follows:

$$H = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

H = the Brinell hardness number, P = load applied, D = diameter of ball, d = the diameter of the ball impression.

Diam.	Kg. 5000	Kg. 3000	Kg. 1000	Kg. 500	Diam.	Kg. 5000	Kg. 3000	Kg. 1000	Kg. 500
2.00	1575	945	315	158	4.50	298	179	59.5	29.8
2.05	1499	899	300	150	4.55	291	174	58.1	29.1
2.10	1427	856	285	143	4.60	284	170	56.8	28.4
2.15	1361	817	272	136	4.65	278	167	55.8	27.8
2.20	1299	780	260	130	4.70	271	163	54.3	27.1
2.25	1241	745	248	124	4.75	265	159	53.0	26.5
2.30	1187	712	237	119	4.80	259	156	51.9	25.9
2.35	1137	682	227	114	4.85	254	152	50.7	25.4
2.40	1089	653	218	109	4.90	248	149	49.6	24.8
2.45	1044	627	209	104	4.95	243	146	48.6	24.3
2.50	1002	601	200	100	5.00	238	143	47.5	23.8
2.55	963	578	193	96.3	5.05	233	140	46.5	23.3
2.60	926	555	185	92.6	5.10	228	137	45.5	22.8
2.65	890	534	178	89.0	5.15	223	134	44.6	22.3
2.70	857	514	171	85.7	5.20	218	131	43.7	21.8
2.75	826	495	165	82.6	5.25	214	128	42.8	21.4
2.80	796	477	159	79.6	5.30	209	126	41.9	20.9
2.85	768	461	154	76.8	5.35	205	123	41.0	20.5
2.90	741	444	148	74.1	5.40	201	121	40.2	20.1
2.95	715	429	143	71.5	5.45	197	118	39.4	19.7
3.00	691	415	138	69.1	5.50	193	116	38.6	19.3
3.05	668	401	134	66.8	5.55	189	114	37.9	18.9
3.10	646	388	129	64.6	5.60	186	111	37.1	18.6
3.15	625	375	125	62.5	5.65	182	109	36.4	18.2
3.20	605	363	121	60.5	5.70	178	107	35.7	17.8
3.25	586	352	117	58.6	5.75	175	105	35.0	17.5
3.30	568	341	114	56.8	5.80	172	103	34.3	17.2
3.35	551	331	110	55.1	5.85	168	101	33.7	16.8
3.40	534	321	107	53.4	5.90	165	99.2	33.1	16.5
3.45	518	311	104	51.8	5.95	162	97.3	32.4	16.2
3.50	503	302	101	50.3	6.00	159	95.5	31.8	15.9
3.55	489	293	97.7	48.9	6.05	156	93.7	31.2	15.6
3.60	475	285	94.9	47.5	6.10	153	92.0	30.7	15.3
3.65	461	277	92.3	46.1	6.15	151	90.3	30.1	15.1
3.70	449	269	89.7	44.9	6.20	148	88.7	29.6	14.8
3.75	436	262	87.2	43.6	6.25	145	87.1	29.0	14.5
3.80	424	255	84.9	42.4	6.30	142	85.5	28.5	14.2
3.85	413	248	82.6	41.3	6.35	140	84.0	28.0	14.0
3.90	402	241	80.4	40.2	6.40	137	82.5	27.5	13.7
3.95	391	235	78.3	39.1	6.45	135	81.0	27.0	13.5
4.00	381	229	76.3	38.1	6.50	133	79.6	26.5	13.3
4.05	371	223	74.3	37.1	6.55	130	78.2	26.1	13.0
4.10	362	217	72.4	36.2	6.60	128	76.8	25.6	12.8
4.15	353	212	70.6	35.3	6.65	126	75.4	25.1	12.6
4.20	344	207	68.8	34.4	6.70	124	74.1	24.7	12.4
4.25	336	201	67.1	33.6	6.75	121	72.8	24.3	12.1
4.30	328	197	65.5	32.8	6.80	119	71.6	23.9	11.9
4.35	320	192	63.9	32.0	6.85	117	70.4	23.5	11.7
4.40	312	187	62.4	31.2	6.90	115	69.1	23.0	11.5
4.45	305	183	60.9	30.5	6.95	113	68.0	22.7	11.3
					7.00	111	66.8	22.3	11.1

Note: For other pressures the hardness numbers are in proportion to those given in the table; e. g., for 200 kg. are 1/5 of those for 1000 kg., etc.

HARDNESS CONVERSION TABLE

This table only applies to steel of uniform chemical composition and uniform heat treatment, and is not recommended for nonferrous metals or for case hardened steels.

Approximate Relations Between Brinell, Rockwell, Shore, Vickers and Firth Hardnesses and the Tensile Strengths of Carbon and Alloy Steels.

Brinell Dia. in mm., 3000 kg. load 10 mm. ball	Brinell Hardness No.	Vickers or Firth Dia. Hardness No.	Rockwell C 150 kg. load 120° Diamond Cone	Rockwell B 100 kg. load 1/16 in. dia. ball	Shore Scleroscope No.	Tensile Strength 1000 psi.
2.05	*898*	....	..	...	...	*440*
2.10	*857*	....	..	...	...	*420*
2.15	*817*	....	..	...	...	*401*
2.20	*780*	1150	70	...	106	*384*
2.25	*745*	1050	68	...	100	*368*
2.30	*712*	960	66	...	95	*352*
2.35	*682*	885	64	...	91	*337*
2.40	*653*	820	62	...	87	*324*
2.45	*627*	765	60	...	84	*311*
2.50	*601*	717	58	...	81	*298*
2.55	578	675	57	...	78	*287*
2.60	555	633	55	*120*	75	*276*
2.65	534	598	53	*119*	72	*266*
2.70	514	567	52	*119*	70	*256*
2.75	495	540	50	*117*	67	*247*
2.80	477	515	49	*117*	65	*238*
2.85	461	494	47	*116*	63	*229*
2.90	444	472	46	*115*	61	*220*
2.95	429	454	45	*115*	59	*212*
3.00	415	437	44	*114*	57	*204*
3.05	401	420	42	*113*	55	*196*
3.10	388	404	41	*112*	54	*189*
3.15	375	389	40	*112*	52	*182*
3.20	363	375	38	*110*	51	*176*
3.25	352	363	37	*110*	49	*170*
3.30	341	350	36	*109*	48	*165*
3.35	331	339	35	*109*	46	*160*
3.40	321	327	34	*108*	45	*155*
3.45	311	316	33	*108*	44	*150*
3.50	302	305	32	*107*	43	*146*
3.55	293	296	31	*106*	42	*142*
3.60	285	287	30	*105*	40	*138*
3.65	277	279	29	104	39	*134*
3.70	269	270	28	104	38	*131*
3.75	262	263	26	103	37	*128*
3.80	255	256	25	102	37	*125*
3.85	248	248	24	102	36	*122*
3.90	241	241	23	100	35	*119*
3.95	235	235	22	99	34	*116*
4.00	229	229	21	98	33	*113*

Brinell Dia. in mm., 3000 kg. load 10 mm. ball	Brinell Hardness No.	Vickers or Firth Dia. Hardness No.	Rockwell C 150 kg. load 120° Diamond Cone	Rockwell B 100 kg. load 1/16 in. dia. ball	Shore Scleroscope No.	Tensile Strength 1000 psi.
4.05	223	223	20	97	32	*110*
4.10	217	217	*18*	96	31	*107*
4.15	212	212	*17*	96	31	*104*
4.20	207	207	*16*	95	30	*101*
4.25	202	202	*15*	94	30	*99*
4.30	197	197	*13*	93	29	*97*
4.35	192	192	*12*	92	28	*95*
4.40	187	187	*10*	91	28	*93*
4.45	183	183	*9*	90	27	*91*
4.50	179	179	*8*	89	27	*89*
4.55	174	174	*7*	88	26	*87*
4.60	170	170	*6*	87	26	*85*
4.65	166	166	*4*	86	25	*83*
4.70	163	163	*3*	85	25	*82*
4.75	159	159	*2*	84	24	*80*
4.80	156	156	*1*	83	24	*78*
4.85	153	153	..	82	23	*76*
4.90	149	149	..	81	23	*75*
4.95	146	146	..	80	22	*74*
5.00	143	143	..	79	22	*72*
5.05	140	140	..	78	21	*71*
5.10	137	137	..	77	21	*70*
5.15	134	134	..	76	21	*68*
5.20	131	131	..	74	20	*66*
5.25	128	128	..	73	20	*65*
5.30	126	126	..	72	..	*64*
5.35	124	124	..	71	..	*63*
5.40	121	121	..	70	..	*62*
5.45	118	118	..	69	..	*61*
5.50	116	116	..	68	..	*60*
5.55	114	114	..	67	..	*59*
5.60	112	112	..	66	..	*58*
5.65	109	109	..	65	..	*56*
5.70	107	107	..	64	..	*55*
5.75	105	105	..	62	..	*54*
5.80	103	103	..	61	..	*53*
5.85	101	101	..	60	..	*52*
5.90	99	99	..	59	..	*51*
5.95	97	97	..	57	..	*50*
6.00	95	95	..	56	..	*49*

PERCENTAGE REDUCTION OF AREA FOR TENSILE TEST SPECIMENS

Dia.	Area	% R.A.† 0.505 In. Dia	% R.A. 0.506 In. Dia	% R.A. 0.504 In. Dia.
0.251	0.0494	75.3	75.4	75.2
0.252	0.0498	75.1	75.2	75.0
0.253	0.0502	74.9	75.0	74.8
0.254	0.0506	74.7	74.8	74.6
0.255	0.0510	74.5	74.6	74.4
0.256	0.0514	74.3	74.4	74.2
0.257	0.0518	74.1	74.2	74.0
0.258	0.0522	73.9	74.0	73.8
0.259	0.0526	73.7	73.8	73.6
0.260	0.0530	73.5	73.6	73.4
0.261	0.0535	73.3	73.4	73.2
0.262	0.0539	73.0	73.2	73.0
0.263	0.0543	72.9	73.0	72.8
0.264	0.0547	72.7	72.8	72.6
0.265	0.0551	72.5	72.6	72.4
0.266	0.0555	72.3	72.4	72.2
0.267	0.0559	71.9	72.2	72.0
0.268	0.0564	71.8	71.9	71.7
0.269	0.0568	71.6	71.7	71.5
0.270	0.0572	71.4	71.5	71.3
0.271	0.0576	71.2	71.3	71.1
0.272	0.0581	71.0	71.1	70.9
0.273	0.0585	70.8	70.9	70.7
0.274	0.0589	70.6	70.7	70.5
0.275	0.0593	70.4	70.5	70.3
0.276	0.0598	70.1	70.2	70.0
0.277	0.0602	69.9	70.0	69.8
0.278	0.0606	69.7	69.9	69.6
0.279	0.0611	69.5	69.6	69.4
0.280	0.0615	69.3	69.4	69.2
0.281	0.0620	69.0	69.2	69.0
0.282	0.0624	68.8	69.0	68.7
0.283	0.0629	68.6	68.7	68.5
0.284	0.0633	68.4	68.5	68.3
0.285	0.0637	68.2	68.3	68.1
0.286	0.0642	67.9	68.1	67.8
0.287	0.0646	67.7	67.9	67.6
0.288	0.0651	67.5	67.6	67.4
0.289	0.0655	67.3	67.4	67.2
0.290	0.0660	67.0	67.2	66.9
0.291	0.0665	66.8	66.9	66.7
0.292	0.0670	66.5	66.7	66.4
0.293	0.0674	66.3	66.5	66.2
0.294	0.0679	66.1	66.2	66.0
0.295	0.0683	65.9	66.0	65.8
0.296	0.0688	65.6	65.8	65.5
0.297	0.0692	65.4	65.6	65.3
0.298	0.0697	65.2	65.3	65.1
0.299	0.0702	64.9	65.1	64.8
0.300	0.0707	64.7	64.8	64.6
0.301	0.0712	64.4	64.6	64.3
0.302	0.0716	64.2	64.4	64.1
0.303	0.0721	64.0	64.1	63.9
0.304	0.0725	63.8	63.9	63.7
0.305	0.0730	63.5	63.7	63.4
0.306	0.0735	63.3	63.4	63.2
0.307	0.0740	63.0	63.2	62.9
0.308	0.0745	62.8	62.9	62.7
0.309	0.0749	62.6	62.7	62.5
0.310	0.0754	62.3	62.5	62.2
0.311	0.0759	62.1	62.2	62.0
0.312	0.0764	61.8	62.0	61.7
0.313	0.0769	61.6	61.7	61.5
0.314	0.0774	61.3	61.5	61.2
0.315	0.0779	61.1	61.2	61.0
0.316	0.0784	60.8	61.0	60.7
0.317	0.0789	60.6	60.7	60.5
0.318	0.0794	60.3	60.5	60.2
0.319	0.0799	60.1	60.2	60.0
0.320	0.0804	59.8	60.0	59.7
0.321	0.0809	59.6	59.8	59.4
0.322	0.0814	59.4	59.5	59.2
0.323	0.0819	59.1	59.3	58.9
0.324	0.0824	58.8	59.0	58.7
0.325	0.0829	58.6	58.8	58.4
0.326	0.0834	58.3	58.5	58.2
0.327	0.0839	58.1	58.3	57.9
0.328	0.0844	57.8	58.0	57.7
0.329	0.0850	57.5	57.7	57.4
0.330	0.0855	57.3	57.5	57.1
0.331	0.0860	57.0	57.2	56.9
0.332	0.0865	56.8	57.0	56.6
0.333	0.0870	56.5	56.7	56.4
0.334	0.0876	56.2	56.4	56.1
0.335	0.0881	56.0	56.2	55.8
0.336	0.0886	55.7	55.9	55.6
0.337	0.0891	55.5	55.7	55.3
0.338	0.0897	55.2	55.4	55.0
0.339	0.0902	54.9	55.1	54.8
0.340	0.0907	54.7	54.9	54.5
0.341	0.0913	54.4	54.6	54.2
0.342	0.0918	54.1	54.3	54.0
0.343	0.0924	53.8	54.0	53.7
0.344	0.0929	53.6	53.8	53.4
0.345	0.0934	53.3	53.5	53.2
0.346	0.0940	53.0	53.2	52.9
0.347	0.0945	52.8	53.0	52.6
0.348	0.0951	52.5	52.7	52.3
0.349	0.0956	52.2	52.4	52.1
0.350	0.0962	51.9	52.1	51.8
0.351	0.0967	51.7	51.9	51.5
0.352	0.0973	51.4	51.6	51.2
0.353	0.0978	51.1	51.3	51.0
0.354	0.0984	50.8	51.0	50.7
0.355	0.0989	50.6	50.8	50.4
0.356	0.0995	50.3	50.5	50.1
0.357	0.1000	50.0	50.2	49.9
0.358	0.1006	49.8	50.0	49.6
0.359	0.1012	49.5	49.7	49.3
0.360	0.1017	49.2	49.4	49.0
0.361	0.1023	48.9	49.1	48.7
0.362	0.1029	48.6	48.8	48.4
0.363	0.1034	48.4	48.6	48.2
0.364	0.1040	48.1	48.3	47.9
0.365	0.1046	47.8	48.0	47.6
0.366	0.1052	47.5	47.7	47.3
0.367	0.1057	47.2	47.4	47.0
0.368	0.1063	46.9	47.1	46.7
0.369	0.1069	46.6	46.8	46.4
0.370	0.1075	46.3	46.5	46.1
0.371	0.1081	46.0	46.2	45.8
0.372	0.1086	45.8	46.2	45.6
0.373	0.1092	45.5	45.7	45.3
0.374	0.1098	45.2	45.4	45.0
0.375	0.1104	44.9	45.1	44.5
0.376	0.1110	44.6	44.8	44.4
0.377	0.1116	44.3	44.5	44.1
0.378	0.1122	44.0	44.2	43.8
0.379	0.1128	43.7	43.9	43.5

†R. A. = Reduction of Area.

PERCENTAGE REDUCTION OF AREA FOR TENSILE TEST SPECIMENS

Dia.	Area	% R.A.† 0.505 In. Dia.	% R.A. 0.506 In. Dia.	% R.A. 0.504 In. Dia.
0.380	0.1134	43.4	43.6	43.2
0.381	0.1140	43.1	43.3	42.9
0.382	0.1146	42.8	43.0	42.6
0.383	0.1152	42.5	42.7	42.3
0.384	0.1158	42.2	42.4	42.0
0.385	0.1164	41.9	42.1	41.7
0.386	0.1170	41.6	41.8	41.4
0.387	0.1176	41.3	41.5	41.1
0.388	0.1182	41.0	41.2	40.8
0.389	0.1188	40.7	40.9	40.5
0.390	0.1194	40.4	40.6	40.2
0.391	0.1200	40.1	40.3	39.9
0.392	0.1206	39.8	40.0	39.6
0.393	0.1213	39.4	39.7	39.2
0.394	0.1219	39.1	39.4	38.9
0.395	0.1225	38.8	39.1	38.6
0.396	0.1231	38.5	38.8	38.3
0.397	0.1237	38.2	38.5	38.0
0.398	0.1244	37.9	38.1	37.6
0.399	0.1250	37.6	37.8	37.3
0.400	0.1256	37.3	37.5	37.0
0.401	0.1262	37.0	37.2	36.7
0.402	0.1269	36.6	36.9	36.4
0.403	0.1275	36.3	36.6	36.1
0.404	0.1281	36.0	36.3	35.8
0.405	0.1288	35.7	35.9	35.4
0.406	0.1294	35.4	35.6	35.1
0.407	0.1301	35.0	35.3	34.8
0.408	0.1307	34.7	35.0	34.5
0.409	0.1313	34.4	34.7	34.2
0.410	0.1320	34.1	34.3	33.8
0.411	0.1326	33.8	34.0	33.5
0.412	0.1333	33.4	33.7	33.2
0.413	0.1339	33.1	33.4	32.9
0.414	0.1346	32.8	33.0	32.5
0.415	0.1352	32.5	32.8	32.2
0.416	0.1359	32.1	32.4	31.9
0.417	0.1365	31.8	32.1	31.6
0.418	0.1372	31.5	31.7	31.2
0.419	0.1378	31.2	31.4	30.9
0.420	0.1385	30.8	31.1	30.6
0.421	0.1392	30.5	30.7	30.2
0.422	0.1398	30.2	30.4	29.9
0.423	0.1405	29.8	30.1	29.6
0.424	0.1411	29.5	29.8	29.3
0.425	0.1418	29.2	29.5	28.9
0.426	0.1425	28.8	29.1	28.6
0.427	0.1432	28.5	28.8	28.2
0.428	0.1438	28.2	28.5	27.9
0.429	0.1445	27.8	28.1	27.6
0.430	0.1452	27.5	27.8	27.4
0.431	0.1458	27.2	27.5	26.9
0.432	0.1465	26.8	27.1	26.6
0.433	0.1472	26.5	26.8	26.2
0.434	0.1479	26.1	26.4	25.9
0.435	0.1486	25.8	26.1	25.5
0.436	0.1493	25.4	25.7	25.2
0.437	0.1499	25.1	25.4	24.9
0.438	0.1506	24.8	25.1	24.5
0.439	0.1513	24.4	24.7	24.2
0.440	0.1520	24.1	24.4	23.9
0.441	0.1527	23.7	24.0	23.5
0.442	0.1534	23.4	23.7	23.2
0.443	0.1541	23.0	23.3	22.8

Dia.	Area	% R.A.† 0.505 In. Dia.	% R.A. 0.506 In. Dia.	% R.A. 0.504 In. Dia.
0.444	0.1548	22.7	23.0	22.5
0.445	0.1555	22.3	22.6	22.1
0.446	0.1562	22.0	22.3	21.7
0.447	0.1569	21.6	21.9	21.4
0.448	0.1576	21.3	21.6	21.0
0.449	0.1583	20.9	21.2	20.7
0.450	0.1590	20.6	20.9	20.3
0.451	0.1597	20.2	20.5	20.0
0.452	0.1604	19.9	20.2	19.6
0.453	0.1611	19.5	19.9	19.2
0.454	0.1618	19.2	19.5	18.9
0.455	0.1625	18.8	19.2	18.5
0.456	0.1633	18.4	18.8	18.1
0.457	0.1640	18.1	18.4	17.8
0.458	0.1647	17.7	18.1	17.4
0.459	0.1654	17.4	17.7	17.1
0.460	0.1661	17.0	17.4	16.7
0.461	0.1669	16.6	17.0	16.3
0.462	0.1676	16.3	16.6	16.0
0.463	0.1683	15.9	16.3	15.6
0.464	0.1690	15.6	15.9	15.3
0.465	0.1698	15.2	15.5	14.9
0.466	0.1705	14.8	15.2	14.5
0.467	0.1712	14.5	14.8	14.2
0.468	0.1720	14.1	14.4	13.8
0.469	0.1727	13.7	14.1	13.4
0.470	0.1734	13.4	13.7	13.1
0.471	0.1742	13.0	13.3	12.7
0.472	0.1749	12.6	13.0	12.3
0.473	0.1757	12.2	12.6	11.9
0.474	0.1764	11.9	12.2	11.6
0.475	0.1772	11.5	11.8	11.2
0.476	0.1779	11.1	11.5	10.8
0.477	0.1787	10.7	11.1	10.4
0.478	0.1794	10.4	10.8	10.1
0.479	0.1802	10.0	10.3	9.7
0.480	0.1809	9.6	10.0	9.3
0.481	0.1817	9.2	9.6	8.9
0.482	0.1824	8.9	9.3	8.6
0.483	0.1832	8.5	8.9	8.2
0.484	0.1839	8.1	8.5	7.8
0.485	0.1847	7.7	8.1	7.4
0.486	0.1855	7.3	7.7	7.0
0.487	0.1862	7.0	7.4	6.7
0.488	0.1870	6.6	7.0	6.3
0.489	0.1878	6.2	6.6	5.9
0.490	0.1885	5.8	6.2	5.5
0.491	0.1893	5.4	5.8	5.1
0.492	0.1901	5.0	5.4	4.7
0.493	0.1908	4.7	5.1	4.4
0.494	0.1916	4.3	4.7	4.0
0.495	0.1924	3.9	4.3	3.6
0.496	0.1932	3.5	3.9	3.2
0.497	0.1940	3.1	3.5	2.8
0.498	0.1947	2.7	3.1	2.4
0.499	0.1955	2.3	2.7	2.0
0.500	0.1963	1.9	2.3	1.6
0.501	0.1971	1.4	1.9	1.2
0.502	0.1979	1.1	1.5	0.8
0.503	0.1987	0.8	1.1	0.4
0.504	0.1995	0.4	0.7	0.0
0.505	0.2002	0.0	0.4	
0.506	0.2010		0.0	

LOAD CONVERSION TABLE

TONS PER SQUARE INCH TO POUNDS PER SQUARE INCH					
Tons per Sq. in.	Pounds per Sq. in.	Tons per Sq. in.	Pounds per Sq. in.	Tons per Sq. in.	Pounds per Sq. in.
10.0	22,400	35.0	78,400	70	156,800
10.5	23,520	35.5	79,520	71	159,040
11.0	24,640	36.0	80,640	72	161,280
11.5	25,760	36.5	81,760	73	163,520
12.0	26,880	37.0	82,880	74	165,760
12.5	28,000	37.5	84,000	75	168,000
13.0	29,120	38.0	85,120	76	170,240
13.5	30,240	38.5	86,240	77	172,480
14.0	31,360	39.0	87,360	78	174,720
14.5	32,480	39.5	88,480	79	176,960
15.0	33,600	40.0	89,600	80	179,200
15.5	34,720	40.5	90,720	81	181,440
16.0	35,840	41.0	91,840	82	183,680
16.5	36,960	41.5	92,960	83	185,920
17.0	38,080	42.0	94,080	84	188,160
17.5	39,200	42.5	95,200	85	190,400
18.0	40,320	43.0	96,320	86	192,640
18.5	41,440	43.5	97,440	87	194,880
19.0	42,560	44.0	98,560	88	197,120
19.5	43,680	44.5	99,680	89	199,360
20.0	44,800	45.0	100,800	90	201,600
20.5	45,920	45.5	101,920	91	203,840
21.0	47,040	46.0	103,040	92	206,080
21.5	48,160	46.5	104,160	93	208,320
22.0	49,280	47.0	105,280	94	210,560
22.5	50,400	47.5	106,400	95	212,800
23.0	51,520	48.0	107,520	96	215,040
23.5	52,640	48.5	108,640	97	217,280
24.0	53,760	49.0	109,760	98	219,520
24.5	54,880	49.5	110,880	99	221,760
25.0	56,000	50	112,000	100	224,000
25.5	57,120	51	114,240	101	226,240
26.0	58,240	52	116,480	102	228,480
26.5	59,360	53	118,720	103	230,720
27.0	60,480	54	120,960	104	232,960
27.5	61,600	55	123,200	105	235,200
28.0	62,720	56	125,440	106	237,440
28.5	63,840	57	127,680	107	239,680
29.0	64,960	58	129,920	108	241,920
29.5	66,080	59	132,160	109	244,160
30.0	67,200	60	134,400	110	246,400
30.5	68,320	61	136,640	111	248,640
31.0	69,440	62	138,880	112	250,880
31.5	70,560	63	141,120	113	253,120
32.0	71,680	64	143,360	114	255,360
32.5	72,800	65	145,600	115	257,600
33.0	73,920	66	147,840	116	259,840
33.5	75,040	67	150,080	117	262,080
34.0	76,160	68	152,320	118	264,320
34.5	77,280	69	154,560	119	266,560

KILOGRAMS PER SQUARE MILLIMETER TO POUNDS PER SQUARE INCH					
Kg. per Sq. mm.	Pounds per Sq. in.	Kg. per Sq. mm.	Pounds per Sq. in.	Kg. per Sq. mm.	Pounds per Sq. in.
10	14,223	60	85,340	110	156,457
11	15,646	61	86,763	111	157,880
12	17,068	62	88,185	112	159,302
13	18,490	63	89,607	113	160,724
14	19,913	64	91,030	114	162,147
15	21,335	65	92,452	115	163,569
16	22,757	66	93,874	116	164,991
17	24,180	67	95,297	117	166,414
18	25,602	68	96,719	118	167,836
19	27,024	69	98,141	119	169,258
20	28,447	70	99,564	120	170,681
21	29,869	71	100,986	121	172,103
22	31,291	72	102,408	122	173,525
23	32,714	73	103,831	123	174,948
24	34,136	74	105,253	124	176,370
25	35,558	75	106,675	125	177,792
26	36,981	76	108,098	126	179,215
27	38,403	77	109,520	127	180,637
28	39,826	78	110,943	128	182,059
29	41,248	79	112,365	129	183,482
30	42,670	80	113,787	130	184,904
31	44,093	81	115,210	131	186,327
32	45,515	82	116,632	132	187,749
33	46,937	83	118,054	133	189,171
34	48,360	84	119,477	134	190,594
35	49,782	85	120,899	135	192,016
36	51,204	86	122,321	136	193,438
37	52,627	87	123,744	137	194,861
38	54,049	88	125,166	138	196,283
39	55,471	89	126,588	139	197,705
40	56,894	90	128,011	140	199,128
41	58,316	91	129,433	141	200,550
42	59,738	92	130,855	142	201,972
43	61,161	93	132,278	143	203,395
44	62,583	94	133,700	144	204,817
45	64,005	95	135,122	145	206,239
46	65,428	96	136,545	146	207,662
47	66,850	97	137,967	147	209,084
48	68,272	98	139,389	148	210,506
49	69,695	99	140,812	149	211,929
50	71,117	100	142,234	150	213,351
51	72,539	101	143,656	151	214,773
52	73,962	102	145,079	152	216,196
53	75,384	103	146,501	153	217,618
54	76,806	104	147,923	154	219,040
55	78,229	105	149,346	155	220,463
56	79,651	106	150,768	156	221,885
57	81,073	107	152,190	157	223,307
58	82,496	108	153,613	158	224,730
59	83,918	109	155,035	159	226,152

COMPARISON OF POUNDS AND TONS IN USE IN U.S.A.

Avoirdupois Pounds	Kilograms	Short Tons	Long Tons	Metric Tons
1	.45359	.0005	.00044643	.00045359
2	.90718	.0010	.00089286	.00090718
3	1.36078	.0015	.00133929	.00136078
4	1.81437	.0020	.00178571	.00181437
5	2.26796	.0025	.00223214	.00226796
6	2.72155	.0030	.00267857	.00272155
7	3.17515	.0035	.00312500	.00317515
8	3.62874	.0040	.00357143	.00362874
9	4.08233	.0045	.00401786	.00408233
2.20462	1	.00110231	.00098421	.001
4.40924	2	.00220462	.00196841	.002
6.61387	3	.00330693	.00295262	.003
8.81849	4	.00440924	.00393683	.004
11.02311	5	.00551156	.00492103	.005
13.22773	6	.00661387	.00590524	.006
15.43236	7	.00771618	.00688944	.007
17.63698	8	.00881849	.00787365	.008
19.84160	9	.00992080	.00885786	.009
2000	907.18	1	.89287	.90718
4000	1814.37	2	1.78571	1.81437
6000	2721.55	3	2.67857	2.72155
8000	3628.74	4	3.57143	3.62874
10000	4535.92	5	4.46429	4.53592
12000	5443.11	6	5.35714	5.44311
14000	6350.29	7	6.25000	6.35029
16000	7257.48	8	7.14286	7.25748
18000	8164.66	9	8.03571	8.16466
2240	1016.05	1.12	1	1.01605
4480	2032.09	2.24	2	2.03209
6720	3048.14	3.36	3	3.04814
8960	4064.19	4.48	4	4.06419
11200	5080.24	5.60	5	5.08024
13440	6096.28	6.72	6	6.09628
15680	7112.32	7.84	7	7.11232
17920	8128.38	8.96	8	8.12838
20160	9144.42	10.08	9	9.14442
2204.62	1000	1.10231	.98421	1
4409.24	2000	2.20462	1.96841	2
6613.87	3000	3.30693	2.95262	3
8818.49	4000	4.40924	3.93683	4
11023.11	5000	5.51156	4.92103	5
13227.73	6000	6.61887	5.90524	6
15432.36	7000	7.71618	6.88944	7
17636.98	8000	8.81849	7.87365	8
19841.60	9000	9.92080	8.85786	9

SQUARES AND ROUND BARS

WEIGHTS AND AREAS

Size, Inches	Weight, Lbs. per Foot		Area, Square Inches		Size, Inches	Weight, Lbs. per Foot		Area, Square Inches	
	□	○	□	○		□	○	□	○
0					3	30.60	24.03	9.000	7.069
1/16	.013	.010	.0039	.0031	1/16	31.89	25.05	9.379	7.366
1/8	.053	.042	.0156	.0123	1/8	33.20	26.08	9.766	7.670
3/16	.120	.094	.0352	.0276	3/16	34.54	27.13	10.160	7.980
1/4	.213	.167	.0625	.0491	1/4	35.91	28.21	10.563	8.296
5/16	.332	.261	.0977	.0767	5/16	37.31	29.30	10.973	8.618
3/8	.478	.376	.1406	.1105	3/8	38.73	30.42	11.391	8.946
7/16	.651	.511	.1914	.1503	7/16	40.18	31.55	11.816	9.281
1/2	.850	.668	.2500	.1963	1/2	41.65	32.71	12.250	9.621
9/16	1.076	.845	.3164	.2485	9/16	43.15	33.89	12.691	9.968
5/8	1.328	1.043	.3906	.3068	5/8	44.68	35.09	13.141	10.321
11/16	1.607	1.262	.4727	.3712	11/16	46.23	36.31	13.598	10.680
3/4	1.913	1.502	.5625	.4418	3/4	47.81	37.55	14.063	11.045
13/16	2.245	1.763	.6602	.5185	13/16	49.42	38.81	14.535	11.416
7/8	2.603	2.044	.7656	.6013	7/8	51.05	40.10	15.016	11.793
15/16	2.988	2.347	.8789	.6903	15/16	52.71	41.40	15.504	12.177
1	3.400	2.670	1.0000	.7854	4	54.40	42.73	16.000	12.566
1/16	3.838	3.015	1.1289	.8866	1/16	56.11	44.07	16.504	12.962
1/8	4.303	3.380	1.2656	.9940	1/8	57.85	45.44	17.016	13.364
3/16	4.795	3.766	1.4102	1.1075	3/16	59.62	46.83	17.535	13.772
1/4	5.313	4.172	1.5625	1.2272	1/4	61.41	48.23	18.063	14.186
5/16	5.857	4.600	1.7227	1.3530	5/16	63.23	49.66	18.598	14.607
3/8	6.428	5.049	1.8906	1.4849	3/8	65.08	51.11	19.141	15.033
7/16	7.026	5.518	2.0664	1.6230	7/16	66.95	52.58	19.691	15.466
1/2	7.650	6.008	2.2500	1.7671	1/2	68.85	54.07	20.250	15.904
9/16	8.301	6.519	2.4414	1.9175	9/16	70.78	55.59	20.816	16.349
5/8	8.978	7.051	2.6406	2.0739	5/8	72.73	57.12	21.391	16.800
11/16	9.682	7.604	2.8477	2.2365	11/16	74.71	58.67	21.973	17.257
3/4	10.413	8.178	3.0625	2.4053	3/4	76.71	60.25	22.563	17.721
13/16	11.170	8.773	3.2852	2.5802	13/16	78.74	61.85	23.160	18.190
7/8	11.953	9.388	3.5156	2.7612	7/8	80.80	63.46	23.766	18.665
15/16	12.763	10.024	3.7539	2.9483	15/16	82.89	65.10	24.379	19.147
2	13.600	10.681	4.0000	3.1416	5	85.00	66.76	25.000	19.635
1/16	14.463	11.359	4.2539	3.3410	1/16	87.14	68.44	25.629	20.129
1/8	15.353	12.058	4.5156	3.5466	1/8	89.30	70.14	26.266	20.629
3/16	16.270	12.778	4.7852	3.7583	3/16	91.49	71.86	26.910	21.135
1/4	17.213	13.519	5.0625	3.9761	1/4	93.71	73.60	27.563	21.648
5/16	18.182	14.280	5.3477	4.2000	5/16	95.96	75.36	28.223	22.166
3/8	19.178	15.062	5.6406	4.4301	3/8	98.23	77.15	28.891	22.691
7/16	20.201	15.866	5.9414	4.6664	7/16	100.53	78.95	29.566	23.221
1/2	21.250	16.690	6.2500	4.9087	1/2	102.85	80.78	30.250	23.758
9/16	22.326	17.534	6.5664	5.1572	9/16	105.20	82.62	30.941	24.301
5/8	23.428	18.400	6.8906	5.4119	5/8	107.58	84.49	31.641	24.850
11/16	24.557	19.287	7.2227	5.6727	11/16	109.98	86.38	32.348	25.406
3/4	25.713	20.195	7.5625	5.9396	3/4	112.41	88.29	33.063	25.967
13/16	26.895	21.123	7.9102	6.2126	13/16	114.87	90.22	33.785	26.535
7/8	28.103	22.072	8.2656	6.4918	7/8	117.35	92.17	34.516	27.109
15/16	29.338	23.042	8.6289	6.7771	15/16	119.86	94.14	35.254	27.688
3	30.600	24.033	9.0000	7.0686	6	122.40	96.13	36.000	28.274

SQUARE AND ROUND BARS

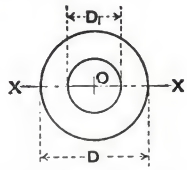
WEIGHTS AND AREAS

Size, Inches	Weight, Lbs. per Foot		Area, Square Inches		Size, Inches	Weight, Lbs. per Foot		Area, Square Inches	
	□	○	□	○		□	○	□	○
6	122.40	96.13	36.000	28.274	9	275.40	216.30	81.000	63.617
1/16	124.96	98.15	36.754	28.866	1/1	279.24	219.31	82.129	64.504
1/8	127.55	100.18	37.516	29.465	1/8	283.10	222.35	83.266	65.397
3/16	130.17	102.23	38.285	30.069	3/16	286.99	225.41	84.410	66.296
1/4	132.81	104.31	39.063	30.680	1/4	290.91	228.48	85.563	67.201
5/16	135.48	106.41	39.848	31.296	5/16	294.86	231.58	86.723	68.112
3/8	138.18	108.53	40.641	31.919	3/8	298.83	234.70	87.891	69.029
7/16	140.90	110.66	41.441	32.548	7/16	302.83	237.84	89.066	69.953
1/2	143.65	112.82	42.250	33.183	1/2	306.85	241.00	90.250	70.882
9/16	146.43	115.00	43.066	33.824	9/16	310.90	244.18	91.441	71.818
5/8	149.23	117.20	43.891	34.472	5/8	314.98	247.38	92.641	72.760
11/16	152.06	119.43	44.723	35.125	11/16	319.08	250.61	93.848	73.708
3/4	154.91	121.67	45.563	35.785	3/4	323.21	253.85	95.063	74.662
13/16	157.79	123.93	46.410	36.450	13/16	327.37	257.12	96.285	75.622
7/8	160.70	126.22	47.266	37.122	7/8	331.55	260.40	97.516	76.589
15/16	163.64	128.52	48.129	37.800	15/16	335.76	263.71	98.754	77.561
7	166.60	130.85	49.000	38.485	10	340.00	267.04	100.000	78.540
1/16	169.59	133.19	49.879	39.175	1/16	344.26	270.38	101.254	79.525
1/8	172.60	135.56	50.766	39.871	1/8	348.55	273.75	102.516	80.516
3/16	175.64	137.95	51.660	40.574	3/16	352.87	277.14	103.785	81.513
1/4	178.71	140.36	52.563	41.282	1/4	357.21	280.55	105.063	82.516
5/16	181.81	142.79	53.473	41.997	5/16	361.58	283.99	106.348	83.525
3/8	184.93	145.24	54.391	42.718	3/8	365.98	287.44	107.641	84.541
7/16	188.07	147.71	55.316	43.445	7/16	370.40	290.91	108.941	85.563
1/2	191.25	150.21	56.250	44.179	1/2	374.85	294.41	110.250	86.590
9/16	194.45	152.72	57.191	44.918	9/16	379.33	297.92	111.566	87.624
5/8	197.68	155.26	58.141	45.664	5/8	383.83	301.46	112.891	88.664
11/16	200.93	157.81	59.098	46.415	11/16	388.36	305.02	114.223	89.710
3/4	204.21	160.39	60.063	47.173	3/4	392.91	308.59	115.563	90.763
13/16	207.52	162.99	61.035	47.937	13/16	397.49	312.19	116.910	91.821
7/8	210.85	165.60	62.016	48.707	7/8	402.10	315.81	118.266	92.886
15/16	214.21	168.24	63.004	49.483	15/16	406.74	319.45	119.629	93.957
8	217.60	170.90	64.000	50.265	11	411.40	323.11	121.000	95.033
1/16	221.01	173.58	65.004	51.054	1/16	416.09	326.80	122.379	96.116
1/8	224.45	176.29	66.016	51.849	1/8	420.80	330.50	123.766	97.205
3/16	227.92	179.01	67.035	52.649	3/16	425.54	334.22	125.160	98.301
1/4	231.41	181.75	68.063	53.456	1/4	430.31	337.97	126.563	99.402
5/16	234.93	184.52	69.098	54.269	5/16	435.11	341.73	127.973	100.510
3/8	238.48	187.30	70.141	55.088	3/8	439.93	345.52	129.391	101.623
7/16	242.05	190.11	71.191	55.914	7/16	444.78	349.33	130.816	102.743
1/2	245.65	192.93	72.250	56.745	1/2	449.65	353.16	132.250	103.869
9/16	249.28	195.78	73.316	57.583	9/16	454.55	357.00	133.691	105.001
5/8	252.93	198.65	74.391	58.426	5/8	459.48	360.87	135.141	106.139
11/16	256.61	201.54	75.473	59.276	11/16	464.43	364.76	136.598	107.284
3/4	260.31	204.45	76.563	60.132	3/4	469.41	368.68	138.063	108.434
13/16	264.04	207.38	77.660	60.994	13/16	474.42	372.61	139.535	109.591
7/8	267.80	210.33	78.766	61.863	7/8	479.45	376.56	141.016	110.754
15/16	271.59	213.31	79.879	62.737	15/16	484.51	380.54	142.504	111.923
9	275.40	216.30	81.000	63.617	12	489.60	384.53	144.000	113.098

SOLID AND HOLLOW SHAFTING

WITH

WEIGHT AND TORSIONAL STRENGTH REDUCTIONS OF SOLID SHAFT BY HOLE PER CENT



D, In. $GI_p = \frac{EI_x}{1.30}$ $S_p = 2S_x$	DIAMETER OF AXIAL HOLE, Inches, D_i. 1st line = % strength reduction from solid, D * 2nd line = % weight reduction from solid, D †														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	6.25														
1.812(7)	25.00														
1.5708															
3	1.23	19.75													
9.175(7)	11.11	44.44													
5.3015															
4	0.39	6.25	31.64												
2.900(8)	6.25	25.00	56.25												
12.566															
5	0.16	2.56	12.96	40.96											
7.080(8)	4.00	16.00	36.00	64.00											
24.544															
6	0.08	1.23	6.25	19.75	48.23										
1.468(9)	2.78	11:11	25.00	44.44	69.44										
42.412															
7	0.04	0.67	3.37	10.66	26.03	53.98									
2.720(9)	2.04	8.16	18.37	32.65	51.02	73.47									
67.348															
8	0.02	0.39	1.98	6.25	15.26	31.64	58.62								
4.640(9)	1.56	6.25	14.06	25.00	39.06	56.25	76.56								
100.53															
9	0.02	0.24	1.23	3.90	9.53	19.75	36.60	62.43							
7.432(9)	1.23	4.94	11.11	19.75	30.86	44.44	60.49	79.01							
143.14															
10	0.01	0.16	0.81	2.56	6.25	12.96	24.01	40.96	65.61						
11.33 (9)	1.00	4.00	9.00	16.00	25.00	36.00	49.00	64.00	81.00						
196.35															
11				1.75	4.27	8.85	16.40	27.98	44.81	68.30					
16.59 (9)				13.22	20.66	29.75	40.50	52.89	66.94	82.64					
261.34															
12				1.23	3.01	6.25	11.58	19.75	31.64	48.23	70.61				
23.49 (9)				11.11	17.36	25.00	34.03	44.44	56.25	69.44	84.03				
339.29															
13				0.90	2.19	4.54	8.41	14.34	22.97	35.01	51.26	72.60			
32.35 (9)				9.47	14.79	21.30	28.99	37.87	47.93	59.17	71.60	85.21			
431.38															
14				0.67	1.63	3.37	6.25	10.66	17.08	26.03	38.11	53.98	74.35		
43.52 (9)				8.16	12.76	18.37	25.00	32.65	41.33	51.02	61.73	73.47	86.22		
538.78															
15				0.51	1.23	2.56	4.74	8.09	12.96	19.75	28.92	40.96	56.42	75.88	
57.35 (9)				7.11	11.11	16.00	21.78	28.44	36.00	44.44	53.78	64.00	75.11	87.11	
662.68															
16				0.39	0.95	1.98	3.66	6.25	10.01	15.26	22.34	31.64	43.58	58.62	77.25
74.24 (9)				6.25	9.77	14.06	19.14	25.00	31.64	39.06	47.27	56.25	66.02	76.56	87.89
804.25															
17				0.31	0.75	1.55	2.87	4.90	7.86	11.97	17.53	24.83	34.20	46.00	60.61
94.61 (9)				5.54	8.65	12.46	16.96	22.15	28.03	34.60	41.87	49.83	58.48	67.82	77.85
964.67															
18				0.24	0.60	1.23	2.29	3.90	6.25	9.53	13.95	19.75	27.21	36.60	48.23
118.9 (9)				4.94	7.72	11.11	15.12	19.75	25.00	30.86	37.35	44.44	52.16	60.49	69.44
1145.1															

NOTES ON SHAFTING DESIGN AND THE USE OF THE TABLES.

(9) represents 1,000,000,000 times. For example, 1.812(7) = 18,120,000

SOLID SHAFT of DIAMETER, D inches.

STIFFNESS, Inch²-Pounds. TORSIONAL STIFFNESS = (GI_p). BENDING STIFFNESS = (EI_x) = 1.30 (GI_p).

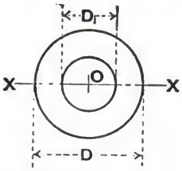
STRENGTH COEFFICIENT (SECTION MODULUS), In.³ Pole O for torsion; axis X-X for bending. Torsional Coefficient = S_p. Bending Coefficient = S_x. $S_p = 2\,S_x$.

HOLLOW SHAFT (H) of Outside Diameter D and Inside Diameter D_i.

STIFFNESS, $(GI_p)_H = (GI_p)_D - (GI_p)_{Di}$. STRENGTH $(S_p)_H = 2(GI_p)_H / D$. (Not $(S_p)_D - (S_p)_{Di}$.

*Decrease in Strength = $(D_i / D)^4 \times 100\%$. †Decrease in Weight = $(D_i / D)^2 \times 100\%$ Based on solid D.

SOLID AND HOLLOW SHAFTING



WITH

WEIGHT AND TORSIONAL STRENGTH REDUCTIONS OF SOLID SHAFT BY HOLE PER CENT

D, In. / $GI_p = \frac{EI_x}{1.30}$ / $S_p = 2S_x$	DIAMETER OF AXIAL HOLE, Inches, D_i — 1st line = % strength reduction from solid, D. 2d line = % weight reduction from solid, D.											
	4	5	6	7	8	9	10	11	12	13	14	15
19	0.20	0.48	0.99	1.84	3.14	5.03	7.67	11.23	15.91	21.92	29.48	38.85
147.6(9)	4.43	6.93	9.97	13.57	17.73	22.44	27.70	33.52	39.89	46.81	54.29	62.33
1346.8												
20	0.16	0.39	0.81	1.50	2.56	4.10	6.25	9.15	12.96	17.85	24.01	31.64
181.2(9)	4.00	6.25	9.00	12.25	16.00	20.25	25.00	30.25	36.00	42.25	49.00	56.25
1570.8												
21	0.13	0.32	0.67	1.23	2.11	3.37	5.14	7.53	10.66	14.69	19.75	26.03
220.3(9)	3.63	5.67	8.16	11.11	14.51	18.37	22.68	27.44	32.65	38.32	44.44	51.02
1818.4												
22	0.11	0.27	0.55	1.02	1.75	2.80	4.27	6.25	8.85	12.19	16.40	21.61
265.4(9)	3.31	5.17	7.44	10.12	13.22	16.74	20.66	25.00	29.75	34.92	40.50	46.49
2090.7												
23	0.09	0.22	0.46	0.86	1.46	2.34	3.57	5.23	7.41	10.21	13.73	18.09
317.0(9)	3.02	4.73	6.81	9.26	12.10	15.31	18.90	22.87	27.22	31.95	37.05	42.53
2389.0												
24	0.08	0.19	0.39	0.72	1.23	1.98	3.01	4.41	6.25	8.61	11.58	15.26
375.8(9)	2.78	4.34	6.25	8.51	11.11	14.06	17.36	21.01	25.00	29.34	34.03	39.06
2714.3												
25	0.07	0.16	0.33	0.61	1.05	1.68	2.56	3.75	5.31	7.31	9.83	12.96
442.5(9)	2.56	4.00	5.76	7.84	10.24	12.96	16.00	19.36	23.04	27 04	31.36	36.00
3068.0												
26	0.06	0.14	0.28	0.53	0.90	1.44	2.19	3.20	4.54	6.25	8.41	11.08
517.7(9)	2.37	3.70	5.33	7.25	9.47	11.98	14.79	17.90	21.30	25.00	28.99	33.28
3451.0												
27	0.05	0.12	0.24	0.45	0.77	1.23	1.88	2.75	3.90	5.37	7.23	9.53
602.0(9)	2.19	3.43	4.94	6.72	8.78	11.11	13.72	16.60	19.75	23.18	26.89	30.86
3864.7												
28	0.04	0.10	0.21	0.39	0.67	1.07	1.63	2.38	3.37	4.65	6.25	8.24
696.3(9)	2.04	3.19	4.59	6.25	8.16	10.33	12.76	15.43	18.37	21.56	25.00	28.70
4310.3												
29	0.04	0.09	0.18	0.34	0.58	0.93	1.41	2.07	2.93	4.04	5.43	7.16
801.2(9)	1.90	2.97	4.28	5.83	7.61	9.63	11.89	14.39	17.12	20.10	23.31	26.75
4788.8												
30	0.03	0.08	0.16	0.30	0.51	0.81	1.23	1.81	2.56	3.53	4.74	6.25
917.6(9)	1.78	2.78	4.00	5.44	7.11	9.00	11.11	13.44	16.00	18.78	21.78	25.00
5301.5												
31	0.03	0.07	0.14	0.26	0.44	0.71	1.08	1.59	2.25	3.09	4.16	5.48
1046 (9)	1.66	2.60	3.75	5.10	6.66	8.43	10.41	12.59	14.98	17.59	20.40	23.41
5849.5												
32	0.02	0.06	0.12	0.23	0.39	0.63	0.95	1.40	1.98	2.72	3.66	4.83
1188 (9)	1.56	2.44	3.52	4.79	6.25	7.91	9.77	11.82	14.06	16.50	19.14	21.97
6434.0												
33	0.02	0.05	0.11	0.20	0.35	0.55	0.84	1.23	1.75	2.41	3.24	4.27
1343 (9)	1.47	2.30	3.31	4.50	5.88	7.44	9.18	11.11	13.22	15.52	18.00	20.66
7056.2												
34	0.02	0.05	0.10	0.18	0.31	0.49	0.75	1.10	1.55	2.14	2.87	3.79
1514 (9)	1.38	2.16	3.11	4.24	5.54	7.01	8.65	10.47	12.46	14.62	16.96	19.46
7717.3												
35	0.02	0.04	0.09	0.16	0.27	0.44	0.67	0.98	1.38	1.90	2.56	3.37
1700 (9)	1.31	2.04	2.94	4.00	5.22	6.61	8.16	9.88	11.76	13.80	16.00	18.37
8418.5												

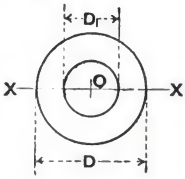
In the tables above, per cent decrease in strength or weight may be found on the line corresponding to the solid shaft diameter and in the column corresponding to the hole diameter.

Tension Modulus of Elasticity = E = 30,000,000 lb. per sq. in. Poisson's Ratio = $(1/m)$ = .300.
Shearing " " Rigidity = G = ½E/(1 + 1/m) = 30,000,000/2.60 = 11,538,500 lb. per sq. in.
MOMENTS APPLIED at SECTION. In.-Lb. BENDING = M_B. TORSION = M_T.
DISTORTION BETWEEN TWO SECTIONS. TORSION; ϕ = Radians Twist. BENDING; y = Inches Deflection.
DISTORTION AT SECTION. TORSION; $d\phi/dx$ = Radians twist per inch. BENDING; d^2y/dx^2 = Curvature, Inch^{-1}.
$M_T = (GI_p)(d\phi/dx)$; $(d\phi/dx) = M_T/(GI_p)$. $M_B = (EI_x)(d^2y/dx^2)$; $(d^2y/dx^2) = M_B/(EI_x)$.

SOLID AND HOLLOW SHAFTING

WITH

WEIGHT AND TORSIONAL STRENGTH REDUCTIONS OF SOLID SHAFT BY HOLE PER CENT



DIAMETER OF AXIAL HOLE, Inches, D_i

1st line = % strength reduction from solid, D.
2nd line = % weight reduction from solid, D.

D, In. $GI_p = \frac{EI_x}{1.30}$ $S_p = 2S_x$	16	17	18	19	20	21	22	23	24	25	26	27	28	29
17 94.61(9) 964.67	78.47 88.58													
18 118.9(9) 1145.1	62.43 79.01	79.56 89.20												
19 147.6(9) 1346.8	50.29 70.91	64.09 80.06	80.55 89.75											
20 181.2(9) 1570.8	40.96 64.00	52.20 72.25	65.61 81.00	81.45 90.25										
21 220.3(9) 1818.4	33.70 58.04	42.95 65.53	53.98 73.47	67.01 81.86	82.27 90.70									
22 265.4(9) 2090.7	27.98 52.89	35.65 59.71	44.81 66.94	55.63 74.59	68.30 82.64	83.02 91.16								
23 317.0(9) 2389.0	23.42 48.39	29.85 54.63	37.51 61.25	46.57 68.24	57.18 75.61	69.50 83.36	83.71 91.49							
24 375.8(9) 2714.3	19.75 44.44	25.17 50.17	31.64 56.25	39.28 62.67	48.23 69.44	58.62 76.56	70.61 84.03	84.35 91.84						
25 442.5(9) 3068.0	16.78 40.96	21.38 46.24	26.87 51.84	33.36 57.76	40.96 64.00	49.79 70.56	59.97 77.44	71.64 84.64	84.93 92.16					
26 517.7(9) 3451.0	14.34 37.87	18.28 42.75	22.97 47.93	28.52 53.40	35.01 59.17	42.56 65.24	51.26 71.60	61.24 78.25	72.60 85.21	85.48 92.46				
27 602.0(9) 3864.7	12.33 35.12	15.72 39.64	19.75 44.44	24.52 49.52	30.11 54.87	36.60 60.49	44.08 66.39	52.66 72.57	62.43 79.01	73.50 85.73	85.99 92.73			
28 696.3(9) 4310.3	10.66 32.65	13.59 36.86	17.08 41.33	21.20 46.05	26.03 51.02	31.64 56.25	38.11 61.73	45.53 67.47	53.98 73.47	63.55 79.72	74.35 86.22	86.46 92.98		
29 801.2(9) 4788.8	9.27 30.44	11.81 34.36	14.84 38.53	18.43 42.93	22.62 47.56	27.50 52.44	33.12 57.55	39.57 62.90	46.91 68.49	55.23 74.32	64.61 80.38	75.14 86.68	86.90 93.22	
30 917.6(9) 5301.5	8.09 28.44	10.31 32.11	12.96 36.00	16.09 40.11	19.75 44.44	24.01 49.00	28.92 53.78	34.55 58.78	40.96 64.00	48.23 69.44	56.42 75.11	65.61 81.00	75.88 87.11	87.32 93.44
31 1046 (9) 5849.5	7.10 26.64	9.04 30.07	11.37 33.71	14.11 37.57	17.33 41.62	21.06 45.89	25.37 50.36	30.30 55.05	35.93 59.94	42.30 65.04	49.48 70.34	57.55 75.86	66.56 81.58	76.59 87.51
32 1188 (9) 6434.0	6.25 25.00	7.97 28.22	10.01 31.64	12.43 35.25	15.26 39.06	18.55 43.07	22.34 47.27	26.69 51.66	31.64 56.25	37.25 61.04	43.58 66.02	50.68 71.19	58.62 76.56	67.45 82.13
33 1343 (9) 7056.2	5.53 23.51	7.04 26.54	8.85 29.75	10.99 33.15	13.49 36.73	16.40 40.50	19.75 44.44	23.60 48.58	27.98 52.89	32.94 57.39	38.53 62.08	44.81 66.94	51.83 71.99	59.64 77.23
34 1514 (9) 7717.3	4.90 22.15	6.25 25.00	7.86 28.03	9.75 31.23	11.97 34.60	14.55 38.15	17.53 41.87	20.94 45.76	24.83 49.83	29.23 54.07	34.20 58.48	39.77 63.06	46.00 67.82	52.93 72.75
35 1700 (9) 8418.5	4.37 20.90	5.57 23.59	7.00 26.45	8.68 29.47	10.66 32.65	12.96 36.00	15.61 39.51	18.65 43.18	22.11 47.02	26.03 51.02	30.45 55.18	35.41 59.51	40.96 64.00	47.13 68.65

STRESSES AT SECTION. Lb. per sq. in. BENDING = f_B. TORSION = f_T.

$M_T = f_T S_p$; $f_T = M_T/S_p$. $M_B = f_B S_x$; $f_B = M_B/S_x$.

COMBINED STRESSES AT SECTION. Lb. per sq. in. SHEAR = f_s. DIRECT (Tension or Compression) = f_t.

$2 f_s = \sqrt{4 f_T^2 + f_B^2}$ $2 f_t = f_B + 2 f_s$.

INTER-CONVERSION TABLE FOR UNITS OF ENERGY

MULTIPLY BY

To Convert from	To B.t.u.	To Cal.	To Ft-lb.	To Ft. Tons	To Kg-m.	To Hp-hr.	To Kw-hr.	To Joules (abs.)	To Lb. C.	To Lb. H_2O
B.t.u. (mean)	1.00	0.252	778.000	0.389001	107.563	$0.0_{3}3929$	$0.0_{3}2931$	1054.8	0.046876	0.001031
Calories (mean)	3.968	1.000	3091.36	1.544	426.84	0.001559	0.001163	4185	$0.0_{3}2729$	0.004089
Ft-lb.	0.001285	$0.0_{3}3239$	1.000	0.000500	0.1383	$0.0_{6}5050$	$0.0_{6}3767$	1.355	$0.0_{7}8840$	$0.0_{5}1325$
Ft. Tons	2.571	0.6478	2000.00	1.000	276.511	0.001010	$0.0_{3}7535$	2712.59	$0.0_{3}1768$	0.002649
Kg-m.	0.009297	0.002343	7.23301	0.003617	1.000	$0.0_{5}3653$	$0.0_{5}2725$	9.806	$0.0_{6}6394$	$0.0_{5}9580$
Hp-hr.	2544.99	641.327	1980000	990.004	273747	1.000	0.746000	2685600	0.1750	2.62261
Kw-hr.	3411.57	859.702	2654200	1327.10	366959	1.34041	1.000	3600000	0.2346	3.51562
Joules (absolute)	$0.0_{3}9477$	$0.0_{3}2389$	0.737356	$0.0_{3}3687$	0.101937	$0.0_{6}3725$	$0.0_{6}2778$	1.000	$0.0_{7}6518$	$0.0_{6}9766$
Lbs. C.	14544	3665	113150_{8}	5658	1564396	5.714	4.263	153470_{3}	1.000	14.98
Lbs. H_2O	970.40	244.537	754971	377.487	104379	0.381270	0.284424	1023966	0.06674	1.000

Note: The small subnumeral following a zero indicates that the zero is to be taken that number of times, thus, **$0.0_{3}1428$ is** equivalent to 0.0001428.

The ton used is 2000 lb. "Lb. C" refers to pounds of carbon oxidized, 100% efficiency equivalent to the corresponding number of heat units. "Lb. H_2O" refers to pounds of water evaporated at 100°C. (212°F.) at 100% efficiency.

INTER-CONVERSION TABLE FOR UNITS OF VOLUME AND WEIGHT

MULTIPLY BY

To Convert From	To Cu.in.	To Cu.ft.	To Cu.yd.	To Fl.oz.	To Pt.	To Qt.	To Gal.	To Grain	To Oz.Troy	To Oz.Av.	To Lb.Troy	To Lb. Av.	To C.C. or G.	To L. or Kg.
Cu.in.	1.00000	$0.0_{3}5787$	$0.0_{4}2143$	0.554112	0.034632	0.017316	0.004329	252.891	0.526857	0.578037	0.043905	0.036127	16.3871	0.016387
Cu.ft.	1728.00	1.00000	0.037037	957.505	59.8442	29.9221	7.48052	436996	910.408	998.848	75.8674	62.4280	28316.9	28.3169
Cu.yd.	46656.0	27.0000	1.00000	25852.6	1615.79	807.896	201.974	117990_{3}	24581.0	26968.9	2048.42	1685.56	764556	764.556
Fl.oz.	1.80469	0.001044	$0.0_{4}3868$	1.00000	0.062500	0.031250	0.007813	456.390	0.950813	1.04318	0.079234	0.065199	29.5736	0.029573
Pt.	28.8750	0.016710	$0.0_{3}6189$	16.0000	1.00000	0.500000	0.125000	7302.23	15.2130	16.6908	1.26775	1.04318	473.177	0.473177
Qt.	57.7500	0.033420	0.001238	32.0000	2.00000	1.00000	0.250000	1460.45	30.4260	33.3816	2.53550	2.08635	946.354	0.946354
Gal.	231.000	0.133681	0.004951	128.000	8.00000	4.00000	1.00000	58417.9	121.704	133.527	10.1420	8.34541	3785.42	3.78542
Grain	0.003954	$0.0_{5}2288$	$0.0_{7}8475$	0.002191	$0.0_{3}1369$	$0.0_{4}6850$	$0.0_{4}1712$	1.00000	0.002083	0.002286	$0.0_{3}1735$	$0.0_{3}1428$	0.064799	$0.0_{4}6479$
Oz. Troy	1.89805	0.001098	$0.0_{4}4068$	1.05173	0.065733	0.032867	0.008217	480.000	1.00000	1.09714	0.083333	0.068571	31.1035	0.031104
Oz. Av.	1.72999	0.001001	$0.0_{4}3708$	0.958608	0.059913	0.029957	0.007489	437.500	0.911457	1.00000	0.075955	0.062500	28.3495	0.028350
Lb. Troy	22.7766	0.013181	$0.0_{3}4882$	12.6208	0.788800	0.394400	0.098600	5760.00	12.0000	13.1657	1.00000	0.822857	373.242	0.373242
Lb. Av.	27.6799	0.016018	$0.0_{3}5933$	15.3378	0.958611	0.479306	0.119826	7000.00	14.5833	16.0000	1.21528	1.00000	453.593	0.453593
C.C. or G.	0.061024	$0.0_{4}3531$	$0.0_{5}1308$	0.033814	0.002113	0.001057	$0.0_{3}2642$	15.4323	0.032151	0.035274	0.002679	0.002205	1.00000	0.001000
L. or Kg.	61.0237	0.035315	0.001308	33.8140	2.11337	1.05669	0.264172	15432.3	32.1507	35.2739	2.67923	2.20462	1000.00	1.00000

Note: The small subnumeral following a zero indicates that the zero is to be taken that number of times, thus, $0.0_{3}1428$ is equivalent to 0.0001428.

Values Used in Constructing Table: 1 in. = 2.540001 cm.; 1 cu. in. = 16.387083 g. H_2O at 4°C. (39°F.); 1 lb. av. = 453.5926 g.; 1 gal. = 8.34541 lb.; 1 lb. av. = 27.679886 cu. in. H_2O at 4°C.; 1 lb. av. = 7000 grains; 1 gal. = 58417.87 grains; 231 cu. in. = 1 gal. = 3785.4162 g.

WEIGHTS AND MEASURES

WEIGHTS. United States and British. The grain is the unit. 1 grain = 0.0647987 grams.

AVOIRDUPOIS	Grains	Drams	Ounces	Pounds	Hundred-weight I cwt.	Gross Tons
Net ton = 2,000 lb.	1.	.03657	.002286	.000143	.00000128	.000000064
= .892857	27.34375	1.	.0625	.003906	.00003488	.000001744
gross tons	437.5	16.	1.	.0625	.00055804	.00002790
Pound = 1.215278	7000.	256.	16.	1.	.0089286	.0004464
Troy Lb.	784000.	28672.	1792.	112.	1.	.05
1 stone = .125 cwt.	15680000.	573440.	35840.	2240.	20.	1.

TROY	Grains	Pennyweight	Ounces	Pounds
	1	.041667	.0020833	.0001736
	24	1.	.05	.0041667
	480	20.	1.	.0833333
	5760	240.	12.	1.

175 Troy Ounces = 192 Avoirdupois Ounces.
1 Pound Troy = .822857 Lb. Avoir.

APOTHECARIES'	Grains	Scruples	Drams	Ounces	Pounds
	1	.05	.016667	.0020833	.000173611
	20	1.	.333333	.0416667	.0034722
	60	3.	1.	.125	.0104167
	480	24.	8.	1.	.0833333
	5760	288.	96.	12.	1.

Carat. About 3.2 grains.
Carat, International, 205 milligrams = 3.168 grains.
Carat, sometimes 200 milligrams.
1 ounce = 31.1035 grams.
Apothecaries' pound and ounce as for Troy.

LINEAR MEASURE. United States and British. But, 1 yard U. S. = 1.0000029 yds., British; 1 yard British = 0.9999971 yds., U. S

COMMON MEASURE STATUTE	Inches	Feet	Yards	Rods	Furlongs	Miles
	1	.08333	.02778	.0050505	.00012626	.00001578
	12	1.	.33333	.0606061	.00151515	.00018939
	36	3.	1.	.1818182	.00454545	.00056818
1 U. S. League	198	16.5	5.5	1.	.025	.003125
= 3 statute miles	7920	660.	220.	40.	1	.125
= 24 furlongs	63360	5280.	1760.	320.	8.	1.

ROPE AND CABLE MEASURE

1 inch = .111111 span = .013889 fathom = .0001157 cable's length.
1 span = 9 inches = .125 fathom = .00104167 cable's length.
1 fathom = 6 feet = 8 spans = 72 inches = .008333 cable's length.
1 cable's length = 120 fathoms = 720 feet = 960 spans = 8640 inches.

NAUTICAL MEASURE

1 nautical mile, as adopted by the United States Coast and Geodetic Survey, equals the length of 1 minute of arc of a great circle of a sphere whose surface equals that of the earth = 6080.20 feet = 1.1516 statute miles.
1 league = 3 nautical miles = 18240.60 feet.

GUNTER'S CHAIN

1 link = 7.92 inches = .01 chain = .000125 miles.
1 chain = 100 links = 66 feet = 4 rods = .0125 miles.
1 mile = 80 chains = 8000 links

SQUARE OR LAND MEASURE. United States and British.

COMMON MEASURE STATUTE	Square Inches	Square Feet	Square Yards	Square Rods	Acres	Square Miles
	1	.006944	.0007716			
	144	1	.1111111			
	1296	9	1.	.03306	.0002066	
	39204	272.25	30.25	1	.00625	.00000977
	6272640	43560.	4840.	160.	1.	.0015625
		27878400.	3097600.	102400.	640.	1.

1 rood = 40 square rods. Square of 1 acre = 208.7103 feet square.
1 acre = 4 roods. 1 square chain (Gunter's) = 16 sq. rods = 1/10 acre.
1 sq. rod, sq. pole, or sq. perch = 625 sq. links = 1/160 acre

WEIGHTS AND MEASURES

VOLUME MEASURES

CUBIC OR SOLID MEASURE
United States and British

1 cubic inch = .0005787 cubic foot = .000021433 cubic yard.
1 cubic foot = 1728 cubic inches = .03703704 cubic yard.
1 cubic yard = 27 cubic feet = 46656 cubic inches.
1 cord of wood = 128 cubic feet = Solid 4 x 4 x 8 feet.
1 perch of masonry = 24.75 cubic feet = Solid 16.5 x 1.5 x 1 foot. It is usually taken as 25 cubic feet.
1 British Imperial Gallon (dry or liquid) = 1.03202 U. S. dry gallon = 1.20091 U. S. liquid gallon.

DRY MEASURE
United States only

Pints	Quarts	Gallons	Pecks	Bushels	Cubic Inches
1	.50	.125	.0625	.015625	33.6003125
2	1.	.250	.125	.03125	67.200625
8	4.	1.	.5	.125	268.8025
16	8.	2.	1.	.250	537.605
64	32	8.	4.	1.	2150.42

1 heaped bushel = 1.25 struck bushels, but cone must not be less than 6 inches high.

LIQUID MEASURE
United States only

Gills	Pints	Quarts	Gallons	Barrels	Cubic Inches
1	.25	.125	.03125	.000992	7.21875
4	1.	.5	.125	.003968	28.875
8	2.	1.	.25	.007937	57.75
32	8.	4.	1.	.031746	231.
1008	252.	126.	31.5	1.	7276.5

British Imperial Gallon
= 277.410 cubic inches
= 4545.9631 cm^3.
= 10 pounds avoirdupois of pure water at 62° F. and barometer at 30 inches.
1 fluid dram = 60 minims
= .125 fluid ounce
= .0078125 pint.
1 fluid ounce
480 minims (m) =
8 fluid drams
= .0625 pint
= 29.574 cm^3.

METRIC SYSTEM

LENGTH, CAPACITY, WEIGHT, MEASURES

LENGTH	Kilometer	Hectometer	Decameter	Meter	Decimeter	Centimeter	Millimeter
CAPACITY	Kiloliter Stere	Hectoliter Decistere	Decaliter Centistere	Liter Millistere	Deciliter	Centiliter	Milliliter
WEIGHT	Kilogram	Hectogram	Decagram	Gram	Decigram	Centigram	Milligram
	1	10	100	1000	10000	100,000	1000000
		1	10	100	1000	10000	100000
			1	10	100	1000	10000
				1	10	100	1000
				.1	1	10	100
				.01	.1	1	10
				.001	.01	.1	1

1 myriameter = 10 kilometers = 10,000 meters.
1 tonne = 1000 kilograms = 100 myriagrams = 10 quintals.
1 liter = 1 cubic decimeter.
1 gram = Weight of 1 cubic centimeter of distilled water at its maximum density at sea level in the latitude of Paris with the barometer at 760 millimeters of mercury.

SQUARE or SURFACE MEASURE

Square Kilometer	Square Hectometer, Hectare	Square Decameter, Are	Square Meter, Centiare	Square Decimeter	Square Centimeter	Square Millimeter
1	100	10000	1000000			
	1	100	10000	1000000		
	.01	1	100	10000	1000000	
	.0001	.01	1	100	10000	1000000
	.000001	.0001	.01	1	100	10000
		.000001	.0001	.01	1	100
			.000001	.0001	.01	1

1 square myriameter = 100 square kilometers = 100,000,000 square meters.

CUBIC MEASURE

Cubic Decameter	Cubic Meter	Cubic Decimeter	Cubic Centimeter	Cubic Millimeter
1	1000	1000000	1000000000	
.001	1	1000	1000000	1000000000
.000001	.001	1	1000	1000000
.000000001	.000001	.001	1	1000
	.000000001	.000001	.001	1

1 cubic meter = 1 kiloliter = 1 stere.

EQUIVALENTS OF MEASURE

LENGTHS

1 meter (m) = 10 decimeters (dm) = 100 centimeters (cm) = 1000 millimeters (mm).
1 meter (m) = 0.1 decameter (dkm) = 0.01 hectometer (hm) = 0.001 kilometer (km).
1 meter (m) = 39.37 inches, U. S. Standard = 39.370113 inches, British Standard.
1 millimeter (mm) = 1000 microns (μ) = 0.03937 inch = 39.37 mils.

Meters, m.	Inches, In.	Feet, ft.	Yard, yd.	Rods, r.	Chains, ch.	Miles, U. S.		Kilometers, km.
						Statute	Nautical	
1	39.37	3.28083	1.09361	0.19884	0.04971	0.(3)6214	0.(3)5396	0.001
0.02540	1	0.08333	0.02778	0.(2)5051	0.(2)1263	0.(4)1578	0.(4)1371	0.(4)2540
0.30480	12	1	0.33333	0.06061	0.01515	0.(3)1894	0.(3)1645	0.(3)3048
0.91440	36	3	1	0.18182	0.04545	0.(3)5682	0.(3)4934	0.(3)9144
5.02921	198	16.5	5.5	1	0.25	0.(2)3125	0.(2)2714	0.(2)5029
20.1168	792	66	22	4	1	0.01250	0.01085	0.02012
1609.35	63360	5280	1760	320	80	1	0.86839	1.60935
1853.27	72962.5	6080.20	2026.73	368.497	92.1243	1.15155	1	1.85327
1000	39370	3280.83	1093.61	198.838	49.7096	0.62137	0.53959	1

1 international geographical mile = 1/15° at equator = 7422 m = 4.611808 U. S. statute miles.
1 international nautical mile = 1/60° at meridian = 1852 m = 0.999326 U. S. nautical miles.
1 U. S. nautical mile = 6080.20 feet = 1.15155 statute miles = 1853.27 meters.
1 British nautical mile = 6080.00 feet = 1.15152 statute miles = 1853.19 meters.

SURFACES AND AREAS

1 sq. meter (m^2) = 100 sq. decimeters (dm^2) = 10000 sq. centimeters (cm^2)
1 sq. meter (m^2) = 0.01 are (a) = 0.0001 hectare (ha).
1 sq. millimeter (mm^2) = 0.01 cm^2 = 0.00155 sq. inch = 1973.5 circular mils.
1 are (a) = 1 sq. decameter (dkm) = 0.0247104 acre.

Sq. Meters, m^2.	Sq. Inches, sq. in.	Sq. Feet, sq. ft.	Sq. Yards, sq. yd.	Sq. Rods, sq. r.	Acres, A	Hectares, ha.	Sq. Miles, Statute	Sq. Kilo-meters, km^2.
1	1550.00	10.7639	1.19599	0.03954	0.(3)2471	0.0001	0.(6)3861	0.(5)1
0.(3)6452	1	0.(2)6944	0.(3)7716	0.(4)2551	0.(6)1594	0.(7)6452	0.(9)2491	0.(9)6452
0.09290	144	1	0.11111	0.(2)3673	0.(4)2296	0.(5)9290	0.(7)3587	0.(7)9290
0.83613	1296	9	1	0.03306	0.(3)2066	0.(4)8361	0.(6)3228	0.(6)8361
25.2930	39204	272.25	30.25	1	0.00625	0.(2)2529	0.(5)9766	0.(4)2529
4046.87	6272640	43560	4840	160	1	0.40469	0.(2)1563	0.(2)4047
10000	15499969	107639	11959.9	395.366	2.47104	1	0.(2)3861	0.01
2589999	....	27878400	3097600	102400	640	259.000	1	2.59000
1000000	....	10763867	1195985	39536.6	247.104	100	0.38610	1

Notation .(5) = .00000. For example, .(7)232 = .000000232.

EQUIVALENTS OF MEASURE

VOLUME AND CAPACITY

1 cu. meter (m^3) = 1000 cu. decimeters (dm^3) = 1000000 cu. centimeters (cm^3).
1 liter (*l*) = 10 deciliters (dl) = 100 centiliters (cl) = 1000 milliliters (ml) = 1000 cu. centimeters, (cm^3 or c.c.).
1 liter (*l*) = 0.1 decaliter (dkl) = 0.01 hectoliter (hl) = 1 cu. decimeter (dm^3).

Cubic Deci-meters, dm^3 or Liters, *l*	Cubic Inches, cu. in.	Cubic Feet, cu. ft.	Cubic Yards, cu. yd.	U. S. Quarts		U. S. Gallons		U. S. Bushels, bu.
				Liquid, l. qt.	Dry, d. qt.	Liquid, l. gal.	Dry, d. gal.	
1	61.0234	0.03531	0.(2)1308	1.05668	0.90808	0.26417	0.22702	0.02838
0.01639	1	0.(3)5787	0.(4)2143	0.01732	0.01488	0.(2)4329	0.(2)3720	0.(3)4650
28.3170	1728	1	0.03704	29.9221	25.7140	7.48055	6.42851	0.80356
764.559	46656	27	1	807.896	694.279	201.974	173.570	21.6962
0.94636	57.75	0.03342	0.(2)1238	1	0.85937	0.25	0.21484	0.02686
1.10123	67.2006	0.03889	0.(2)1440	1.16365	1	0.29091	0.25	0.03125
3.78543	231	0.13368	0.(2)4951	4	3.43747	1	0.85937	0.10742
4.40492	268.803	0.15556	0.(2)5761	4.65460	4	1.16365	1	0.125
35.2393	2150.42	1.24446	0.04609	37.2368	32	9.30920	8	1

1 liter per second = 2.11887 cubic feet per minute = 15.8502 U. S. gallons per minute.
1 U. S. gallon = 0.832705 British Imperial gallons.
Weight of water at maximum density, 4°C, 45° Lat., at sea level, 760 mm barometer:
1 cu. ft. = 62.4283 lbs. av. = 28.3170 kg. 1 cu. in. = 0.57804 oz. av. = 16.3872 g.
1 gal., U. S. liquid = 8.34545 lbs. = 3.78543 kg.
1 gal., British Imperial = 10.0221 lbs. = 4.5459631 kg.

MASSES AND WEIGHTS

1 gram (g) = 10 decigrams (dg) = 100 centigrams (cg) = 1000 milligrams (mg).
1 gram (g) = 0.1 decagram (dkg) = 0.01 hectogram (hg) = 0.001 kilogram (kg).
1 kilogram (kg) = 1 liter of water, (4°C, 45° Lat. at sea level) = 15432.35639 grains, U. S. and British Standard

Kilograms, kg.	Grains, gr.	Ounces		Pounds		Tons		
		Troy, oz. t.	Avoir., oz. av.	Troy, lb. t.	Avoir., lb. av.	Net (Short), 2000 lbs.	Gross, (Long), 2240 lbs.	Metric, 1000 kg.
1	15432.4	32.1507	35.2740	2.67923	2.20462	0.(2)1102	0.(3)9842	0.001
0.(4)6480	1	0.(2)2083	0.(2)2286	0.(3)1736	0.(3)1429	0.(7)7143	0.(7)6378	0.(7)6480
0.03110	480	1	1.09714	0.08333	0.06857	0.(4)3429	0.(4)3061	0.(4)3110
0.02835	437.5	0.91146	1	0.07595	0.06250	0.(4)3125	0.(4)2790	0.(4)2835
0.37324	5760	12	13.1657	1	0.82286	0.(3)4114	0.(3)3674	0.(3)3732
0.45359	7000	14.5833	16	1.21528	1	0.00050	0.(3)4464	0.(3)4536
907.185	14000000	29166.7	32000	2430.56	2000	1	0.89286	0.90719
1016.05	15680000	32666.7	35840	2722.22	2240	1.12	1	1.01605
1000	15432356	32150.7	35274.0	2679.23	2204.62	1.10231	0.98421	1

1 long hundredweight (*l*cwt.) = 1/20 long ton = 4 quarters = 8 stone = 112 lbs — 50 8024 kg.
Notation .(5) = .00000. For example, .(7)232 = .0000000232.

EQUIVALENTS OF MEASURE

FORCES OR WEIGHTS PER UNITS OF LENGTH (LINEAR WEIGHTS)

1 dyne per centimeter = 0.00101972 g/cm = .000183719 poundal/in.
1 gram per centimeter = 980.665 dynes/cm = 0.180166 poundal/in.
1 poundal per inch = 5443.11 dynes/cm = 5.55043 g/cm = .0310810 pound/in.

Grams per Centimeter, g/cm	Grains per Inch, gr./in.	Pounds, per Inch, lb./in.	Pounds per Foot, lb./ft.	Pounds per Yard, lb./yd.	Kilograms per Meter, kg/m	Net Tons, (2000 lbs.), per Mile	Gross Tons, (2240 lbs.), per Mile	Metric Tons, (1000 kg), per Kilometer
1	39.1983	0.(2)5600	0.06720	0.20159	0.10	0.17740	0.15839	0.10
0.02551	1	0.(3)1429	0.(2)1714	0.(2)5143	0.(2)2551	0.(2)4526	0.(2)4041	0.(2)2551
178.579	7000	1	12	36	17.8579	31.6800	28.2857	17.8579
14.8816	583.333	0.08333	1	3	1.48816	2.64000	2.35714	1.48816
4.96054	194.444	0.02778	0.33333	1	0.49605	0.88000	0.78571	0.49605
10	391.983	0.05600	0.67197	2.01591	1	1.77400	1.58393	1
5.63698	220.960	0.03157	0.37879	1.13636	0.56370	1	0.89286	0.56370
6.31342	247.475	0.03535	0.42424	1.27273	0.63134	1.12	1	0.63134

FORCES OR WEIGHTS PER UNITS OF AREA (PRESSURE)

1 dyne per sq. centimeter = 0.00101972 g/cm^2 = 0.000466646 poundals/in^2.
1 gram per sq. centimeter = 980.665 dynes/cm^2 = 0.457619 poundals/in^2.
1 poundal per sq. inch = 2142.95 dynes/cm^2 = 2.18520 g/cm^2 = .0310810 pound/in^2.

Kilograms per Sq. Centimeter, kg/cm^2	Pounds per Sq. Inch, lb./in.^{2}	Pounds per Sq. Foot, lb./ft.^{2}	Net Tons, (2000 lbs.), per Sq. Foot	Atmospheres, Standard, 760 mm	Columns of Mercury, (Hg) 13.59593 Sp. G.		Column of Water, Max. Density 4° C	
					Millimeters	Inches	Meters	Feet
1	14.2234	2048.17	1.02408	0.96778	735.514	28.9572	10	32.8083
0.07031	1	144	0.07200	0.06804	51.7116	2.03588	0.70307	2.30665
0.(3)4882	0.(2)6944	1	0.00050	0.(3)4725	0.35911	0.01414	0.(2)4882	0.01602
0.97648	13.8889	2000	1	0.94502	718.216	28.2762	9.76482	32.0367
1.03329	14.6969	2116.35	1.05818	1	760	29.9212	10.3329	33.9006
0.(2)1360	0.01934	2.78468	1.(2)1392	0.(2)1316	1	0.03937	0.01360	0.04461
0.03453	0.49119	70.7310	0.03537	0.03342	25.4001	1	0.34534	1.13299
0.10	1.42234	204.817	0.10241	0.09678	73.5514	2.89572	1	3.28083
0.03048	0.43353	62.4283	0.03121	0.02950	22.4185	0.88262	0.30480	1

FORCES OR WEIGHTS PER UNITS OF VOLUME (DENSITY)

1 dyne per cu. centimeter = 0.00101972 gram/cm^3 = 0.00118528 poundals/in^3.
1 gram per cu. centimeter = 980.665 dynes/cm^3 = 1.162366 poundals/in^3.
1 poundal per cu. inch = 843.680 dynes/cm^3 = 0.860314 g/cm^3 = .0310810 pound/in^3.

Grams per Cu. Centimeter, g/cm^3	Pounds per Cu. Inch, lb./in.^{3}	Pounds per Cu. Foot, lb./ft.^{3}	Pounds per Cu. Yard, lb./yd.^{3}	Kilograms per Cu. Meter, kg/m^3	Pounds per Bushel, U. S.	Pounds per Gallon, Dry, U. S.	Pounds per Gallon, Liquid, U. S.	Kilograms per Hectoliter kg/hl
1	0.03613	62.4283	1685.56	1000	77.6893	9.71116	8.34545	100
27.6797	1	1728	46656	27679.7	2150.42	268.803	231	2767.97
0.01602	0.(3)5787	1	27	16.0184	1.24446	0.15556	0.13368	1.60184
0.(3)5933	0.(4)2143	0.03704	1	0.59327	0.04609	0.(2)5762	0.(2)4951	0.05933
0.001	0.(4)3613	0.06243	1.68556	1	0.07769	0.(2)9711	0.(2)8345	0.10
0.01287	0.(3)4650	0.80356	21.6962	12.8718	1	0.125	0.10742	1.28718
0.10297	0.(2)3720	6.42851	173.570	102.974	8	1	0.85937	10.2974
0.11983	0.(2)4329	7.48052	201.974	119.826	9.30920	1.16365	1	11.9826
0.01	0.(3)3613	0.62428	16.8557	10	0.77689	0.09711	0.08345	1

The dyne is not affected by g. It will accelerate a free mass of 1 gram 1 cm. per second per second. A poundal is a similar force unaffected by g which will accelerate a pound mass 1 ft. per second per second. 1 poundal = 13,825.525 dynes.

Masses remain unchanged irrespective of location. The gravitational **force,** however, on a standard **mass,** varies with location. The standard acceleration of gravity, g, is 980.665 cm/sec^2 or 32.1740 ft./sec^2, for which the weight of a pound of mass is a force of 1 pound, and the weight of a mass of 1 kilogram is a force of 1 kilogram, thereby defining the lb. and kg. as units of force.

Notation: .(5) = .00000. For example, .(7)232 = .0000000232

EQUIVALENTS OF MEASURE

ENERGY, WORK AND HEAT

1 dyne-centimeter = 1 erg = 0.00101972 gram-centimeter = 0.(7)737561 foot-pound.
1 gram-centimeter = 980.665 ergs = 0.(4)723301 foot-pound.
1 foot-pound = 13558208 ergs = 13825.5 gram-centimeters.

Kilogram-meters, kg-m	Foot-Pounds, ft.-lbs.	Horsepower-hour		Poncelet-hours, 100 kg-m-h	Kilowatt-hours, kw-h	Joules, 10^7 ergs, J	Thermal Units	
		U. S., H. P.-h	Metric, 75 kg-m-h				B. T. U.	Calories, kg-cal
1	7.23300	.(5)365303	.(5)370370	.(5)277778	.(5)272406	9.80665	.(2)929717	.(2)234329
.138255	1	.(6)505051	.(6)512056	.(6)384042	.(6)376616	1.355821	.(2)128538	.(3)323972
273,745	1980000	1	1.013872	.760404	.745700	2684525	2545.06	641.464
270,000	1952910	.986318	1	.750000	.735497	2647796	2510.23	632.687
360,000	2603879	1.315091	1.333333	1	.980665	3530394	3346.98	843.583
367,099	2655223	1.341022	1.359624	1.019718	1	3600000	3412.98	860.217
.1019718	.737562	.(6)372506	.(6)377673	.(6)283255	.(6)277778	1	.(3)948049	.(3)238949
107.5599	777.980	.(3)392919	.(3)398370	.(3)298777	.(3)293000	1054.800	1	.252044
426.7521	3086.70	.(2)155894	.(2)158056	.(2)118542	.(2)116250	4185.000	3.96758	1

POWER, RATE OF ENERGY AND HEAT

1 erg per sec. = 1 dyne-cm/sec. = 0.00101972 gram-cm/sec. = 0.(7)737561 foot-pound/sec.
1 gram-centimeter per second = 980.665 ergs/sec. = 0.(4)723301 foot-pound/sec.
1 foot-pound per second = 13558208 ergs/sec. = 13825.5 gram-cm/sec.

Kilogram-meters per Second, kg-m/sec.	Foot-pounds per Second, ft.-lbs./sec.	Horsepower		Poncelet 100 kg-m/sec.	Kilowatt, kw.	Watts, 10^7 ergs/sec.	Thermal Units per Sec.	
		U. S., 550 ft.-lbs./sec.	Metric, 75 kg-m/sec.				B. T. U., B.T.U./sec.	Calorie, kg-cal/sec.
1	7.23300	.0131509	.0133333	.0100000	.00980665	9.80665	.00929717	.00234329
0.138255	1	.00181818	.00184340	.00138255	.00135582	1.35582	.00128538	.(3)323971
76.0404	550.000	1	1.013872	.760404	.74570	745.70	.706959	.178184
75.0000	542.475	.986318	1	.750000	.735497	735.497	.697286	.175746
100.0000	723.300	1.315091	1.33333	1	.980665	980.665	.929715	.234328
101.9718	737.562	1.341022	1.359624	1.019718	1	1000.000	.948047	.238949
.1019718	.737562	.00134102	.00135962	.00101972	.00100000	1	.(3)948047	.(3)238949
107.5599	777.980	1.414510	1.434132	1.075599	1.0548	1054.80	1	.252043
426.7521	3086.70	5.61218	5.69003	4 26752	4.18500	4185.00	3.96758	1

VELOCITIES AND ACCELERATIONS

1 kine = 1 centimeter per second = 0.0328083 foot per second.
1 radian per second = 57.2958 degrees per sec. = 0.159155 revolutions per sec.
1 gravity = 980.665 centimeters per sec. per sec. = 32.1740 feet per sec. per sec.

Meters per Second, m/sec.	Feet per Second, ft./sec.	Miles per Hour, M/h	Knots U. S.	Kilometers per Hour, km/h	Meter per Sec. per Sec. m/sec./sec.	Feet per Sec. per Sec. ft./sec./sec.	Miles per Hour per Sec. M/h/sec.	Kilometers per Hour per Sec. km/h/sec.
1	3.28083	2.23693	1.94254	3.6	....	....	....	....
0.30480	1	0.68182	0.59209	1.09728	....	....	....	....
0.44704	1.46667	1	0.86839	1.60935	....	....	....	....
0.51479	1.68894	1.15155	1	1.85325	....	....	....	....
0.27778	0.91134	0.62137	0.53959	1	....	....	....	....
....	....	....	....	....	1	3.28083	2.23693	3.6
....	....	....	....	....	0.30480	1	0.68182	1.09728
....	....	....	....	....	0.44704	1.46667	1	1.60935
....	....	....	....	....	0.27778	0.91134	0.62137	1

NOTES:—

1 Electrical H. P. = 746.00 watts. But 1 H.P. of 550 ft.-lbs./per sec. = 745.70 watts when g = 980.665 cm/sec^2.
1 Watt = 1 Joule/sec. = 10^7 ergs/sec = 10^7 dyne-cm/sec. = 3.4130 B.T.U. per hour = .23895 cals$_{15}$° per sec.
1 B.T.U. mean = 1054.8 joules = 777.98 ft. lbs. = 1/180 of heat required to raise 1 lb. water from 32° to 212° F.
Based on International Critical Tables values. 1 Cal.$_{15}$° = 4185 joules = 1000 cal.$_{15}$°.

Notation: .(5) = .00000. For example, .(7)232 = .0000000232

COEFFICIENT OF LINEAR EXPANSION

FOR 1 DEGREE CENTIGRADE

FOR 1 DEGREE FAHRENHEIT MULTIPLY BY 5/9

Material	Centigrade	20 to 100	20 to 200	20 to 300	20 to 400	20 to 500	20 to 600	100 to 200	200 to 300	300 to 400	400 to 500	500 to 600
	Fahrenheit	70 to 210	70 to 390	70 to 570	70 to 750	70 to 930	70 to 1110	210 to 390	390 to 570	570 to 750	750 to 930	930 to 1110
Aluminum	Cast	23.8	24.7	25.7	26.7	27.7	28.7	25.5	27.5	29.5	31.5	33.5
Antimony		10.5*										
Arsenic		5.0*										
Bismuth		13.2*										
Brass, Soft (72 Cu, 28 Zn)	Rolled & Ann.	17.8	18.5	19.1	19.8	20.5						
Brass, Soft (66 Cu, 34 Zn)	Rolled & Ann.	19.5	20.0	20.5	21.1	21.6						
Brass, Naval (60 Cu, 1 Sn, 39 Zn)	Rolled	19.8	20.5	21.2	21.8	22.5						
Bronze, Aluminum	Cast	17.6	17.9	19.2								
Bronze, Lead	Cast	19.1	19.2	19.4	19.5	19.6						
Bronze, Manganese	Cast	20.0	20.4	20.8	21.6	22.7						
Bronze, Nickel	Cast	17.3	17.7	18.1	18.4	18.8						
Bronze, Phosphor	Cast	18.1	18.4	18.8	19.1	19.4						
Cadmium		31.6*										
Carbon (Graphite)		7.86*										
Cobalt		12.36*										
Copper	Rolled	16.6	17.1	17.6	18.1	18.6						
Duralumin		23.8	24.7	25.7	26.3	27.2						
Gold		13.8**										
Gun Metal	Cast	18.7	19.1	19.6	20.0	20.4						
Lead		27.09*										
Magnesium		25.8*										
Monel Metal	Rolled	13.9*	14.4*	14.9*	15.5*	16.0*						
" "	"	13.5*	14.1*	14.7*	15.3*	15.9*						
" "	Cast	16.5*	16.6*	16.8*	17.0*	17.2*						
Muntz Metal (60 Cu, 40 Zn)	Rolled	19.5	20.3	21.0	28.0							
Nickel	Rolled	13.1*	13.8*				15.5	13.5	14.8	17.2	16.6	17.1
Nichrome	Rolled	12.4*	13.0*	13.6*	14.1*	14.7*						
Palladium		11.76*										
Platinum		8.99*										
Silicon		7.63*										
Silver		19.21*										
Silver Solders		19.0*	19.2*	19.6*	20.4*	21.3*						
Tantalum		6.5*										
Tin		22.95*										
Tungsten		4.3*	4.4*	4.5*	4.5*	4.6*		4.5	4.6	4.7	4.8	
Zinc		29.76*										

EXPANSION OF WATER

MAXIMUM DENSITY = 1

C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume	C°	Volume
0	1.000126	10	1.000257	30	1.004234	50	1.011877	70	1.022384	90	1.035829
4	1.000000	20	1.001732	40	1.007627	60	1.016954	80	1.029003	100	1.043116

*Starting at 0°C or 32° F.

**25—100° C or 75—210° F.

Data on coefficient of expansion abstracted from "Symposium on Effects of Temperature on the Properties of Metals," American Society for Testing Materials and American Society of Mechanical Engineers, June 1931—See Mochel, p. 509 on "Thermal Expansion of Metals."

All coefficients of expansion in table have been multiplied by 10^6. For example, the table gives 12.4, but the actual coefficient is $12.4 \times 10^{-6} = .0000124$.

COEFFICIENT OF LINEAR EXPANSION

FOR 1 DEGREE CENTIGRADE

FOR 1 DEGREE FAHRENHEIT MULTIPLY BY 5/9

Material — Centigrade	0 to 100	0 to 200	0 to 300	0 to 400	0 to 500	0 to 600	100 to 200	200 to 300	300 to 400	400 to 500	500 to 600	600 to 700
Material — Fahrenheit	32 to 212	32 to 390	32 to 570	32 to 750	32 to 930	32 to 1110	212 to 390	390 to 570	570 to 750	750 to 930	930 to 1110	1110 to 1290
Electrolytic Iron	12.0		13.3			14.7	13.0	14.5	15.3	15.9	16.8	17.4
Armco Iron	12.2	12.8	13.4	13.9	14.5							
Cast Iron:												
1.10 Si, .300 P, 0.70 Mn, 2.75 GC, 3.06 TC	11.1	11.6	12.2	12.7	13.2							
2.00 Si, .255 P, 0.93 Mn, 2.48 GC, 3.12 TC	10.6	11.3	11.9	12.5	13.2							
1.44 Si, .291 P, 0.85 Mn, 2.88 GC, 3.66 TC	10.4	11.1	11.7	12.3	12.9							
Rolled Carbon Steels:												
0.17 C, 0.42 Mn ... Rolled	11.8	12.4	13.0	13.6	14.2							
.08-.18 C, under .55 Mn. Rolled	12.8	13.3	13.9	14.4	14.9							
S.A.E. 1025 ... Rolled	12.0	12.6	13.2	13.7	14.3							
S.A.E. 1035 ... Rolled	12.6	13.1	13.6	14.0	14.5							
O. H. Screw Stock Cold—Drawn	12.2	12.8	13.5	14.2	14.8							
0.41 C, 0.64 Mn .. Annealed	11.1		12.7			14.3	12.2	14.3	15.8	15.7	16.0	16.6
0.59 C, 0.92 Mn .. Annealed	11.1		12.9			14.6	12.5	14.6	15.4	16.1	16.8	16.6
0.49 C, 1.21 Mn .. Annealed	11.3		12.7			14.5	12.2	14.2	16.3	17.7	15.4	16.7
Forged Carbon Steels:												
0.40-0.45 C, 0.40-0.80 Mn, Nor. and Ann.	11.3	12.1	12.9	13.6	14.4							
S.A.E. 1025 ... Q. & D.	12.2	12.8	13.4	14.0	14.7							
S.A.E. 1055 ... do.	11.1	11.8	12.5	13.2	13.9							
Cast Carbon Steels:												
0.25-0.35 C, 0.40-1.00 Mn. Annealed	11.9	12.6	13.3	14.0	14.7							
Nickel Steels:												
0.33 C, 0.78 Mn, 3.59 Ni. Annealed	10.9		12.1			13.8	11.5	13.6	15.2	15.1	15.7	
0.33 C, 0.78 Mn, 3.59 Ni. Q. & D.	10.9	11.6	12.3	12.9	13.6							
5% Ni ... Rolled	11.5	12.0	12.4	12.9	13.4							
35% Ni.	3.7		9.2			13.6	8.4	14.1	16.6	18.4	18.8	19.1
36½% Ni. (Invar)‡	2.9‡				10.9‡							14.6‡
Nickel-Chromium Steels:												
S.A.E. 3145 ... Q. & D.	11.8	12.3	12.9	13.4	14.0							
S.A.E. 3440 ... Q. & D.	11.5	12.1	12.7	13.3	13.9							
Chromium-Vanadium Steels:												
S.A.E. 6115 ... Annealed	11.6		12.7			14.0	12.5	13.7	14.6	15.2	16.0	15.8
S.A.E. 6135 ... Annealed	11.6		12.9			14.6	12.6	14.2	16.0	15.9	16.4	16.9
Chromium-Molybdenum Steels:												
S.A.E. 4140 ... Annealed	11.1	11.7	12.3	13.0	13.6							
Stainless Steels:												
0.30 C, 13.00 Cr ... Annealed	10.0		11.0			12.0	10.6	12.0	12.6	13.5	13.9	13.7
0.13 C, 13.50 Cr ... Annealed	10.2	10.5	10.9	11.3	11.7	12.1*						
0.15 C, 18.00 Cr, 8.00 Ni. Rolled	17.3											20.2@
0.07 C, 18.00 Cr, 8.00 Ni.	16.0											19.0¢

@ 20—1000° C, or 70—1830° F.
¢ 600—1000° C, or 1110—1830° F.
* 0— 800° C, or 32—1470° F.

‡ Invar 2.9—20° to 126° C; 10.9—20° to 506° C; 14.6—20° to 971° C.

Data on coefficient of expansion abstracted from "Symposium on Effects of Temperature on the Properties of Metals," American Society for Testing Materials and American Society of Mechanical Engineers, June 1931—See Mochel, p. 509 on "Thermal Expansion of Metals."

All coefficients of expansion in table have been multiplied by 10^6. For example, the table gives 12.4, but the actual coefficient is $12.4 \times 10^{-6} = .0000124$.

TEMPERATURE CONVERSION TABLE

FAHRENHEIT TO CENTIGRADE

TEMPERATURE CENTIGRADE = 5/9 TEMPERATURE FAHRENHEIT −32

F°	C°	F°	C°	F°	C°	F°	C°	F°	C°
−459.4	−273.00	410	210.00	910	487.77	1410	765.55	1910	1043.33
−400	−240.00	420	215.55	920	493.33	1420	771.11	1920	1048.88
−300	−184.44	430	221.11	930	498.88	1430	776.66	1930	1054.44
−200	−128.88	440	226.66	940	504.44	1440	782.22	1940	1060.00
−100	− 73.33	450	232.22	950	510.00	1450	787.77	1950	1065.55
− 50	− 45.55	460	237.77	960	515.55	1460	793.33	1960	1071.11
− 40	− 40.00	470	243.33	970	521.11	1470	798.88	1970	1076.66
− 30	− 34.44	480	248.88	980	526.66	1480	804.44	1980	1082.22
− 10	− 23.33	490	254.44	990	532.22	1490	810.00	1990	1087.77
0	− 17.77	500	260.00	1000	537.77	1500	815.55	2000	1093.33
10	− 12.22	510	265.55	1010	543.33	1510	821.11	2010	1098.88
20	− 6.66	520	271.11	1020	548.88	1520	826.66	2020	1104.44
30	− 1.11	530	276.66	1030	554.44	1530	832.22	2030	1110.00
40	4 44	540	282.22	1040	560.00	1540	837.77	2040	1115.55
50	10.00	550	287.77	1050	565.55	1550	843.33	2050	1121.11
60	15.55	560	293.33	1060	571.11	1560	848.88	2060	1126.66
70	21.11	570	298.88	1070	576.66	1570	854.44	2070	1132.22
80	26.66	580	304.44	1080	582.22	1580	860.00	2080	1137.77
90	32.22	590	310.00	1090	587.77	1590	865.55	2090	1143.33
100	37.77	600	315.55	1100	593.33	1600	871.11	2100	1148.88
110	43.33	610	321.11	1110	598.88	1610	876.66	2110	1154.44
120	48.88	620	326.66	1120	604 44	1620	882.22	2120	1160.00
130	54.44	630	332.22	1130	610.00	1630	887.77	2130	1165.55
140	60.00	640	337.77	1140	615.55	1640	893 33	2140	1171.11
150	65.55	650	343.33	1150	621.11	1650	898.88	2150	1176.66
160	71.11	660	348.88	1160	626.66	1660	904 44	2160	1182.22
170	76.66	670	354.44	1170	632.22	1670	910.00	2170	1187.77
180	82.22	680	360.00	1180	637.77	1680	915.55	2180	1193.33
190	87.77	690	365.55	1190	643.33	1690	921.11	2190	1198.99
200	93.33	700	371.11	1200	648.88	1700	926.66	2200	1204 44
210	98.88	710	376.66	1210	654.44	1710	932.22	2250	1232.22
220	104.44	720	382.22	1220	660.00	1720	937.77	2300	1260.00
230	110.00	730	387.77	1230	665.55	1730	943.33	2350	1287.77
240	115.55	740	393.33	1240	671.11	1740	948.88	2400	1315.55
250	121.11	750	398.88	1250	676.66	1750	954.44	2450	1343.33
260	126.66	760	404.44	1260	682.22	1760	960.00	2500	1371.11
270	132.22	770	410.00	1270	687.77	1770	965.55	2550	1398.88
280	137.77	780	415.55	1280	693.33	1780	971.11	2600	1426.66
290	143.33	790	421.11	1290	698.88	1790	976.66	2650	1454.44
300	148.88	800	426.66	1300	704.44	1800	982.22	2700	1482.22
310	154.44	810	432.22	1310	710.00	1810	987.77	2750	1510.00
320	160.00	820	437.77	1320	715.55	1820	993.33	2800	1537.77
330	165.55	830	443.33	1330	721.11	1830	998.88	2850	1565.55
340	171.11	840	448.88	1340	726.66	1840	1004.44	2900	1593.33
350	176.66	850	454.44	1350	732.22	1850	1010.00	2950	1621.11
360	182.22	860	460.00	1360	737.77	1860	1015.55	3000	1648.88
370	187.77	870	465.55	1370	743.33	1870	1021.11	3050	1676.66
380	193.33	880	471.11	1380	748.88	1880	1026.66	3100	1704.44
390	198.88	890	476.66	1390	754.44	1890	1032.22	3150	1732.22
400	204.44	900	482.22	1400	760.00	1900	1037.77	3200	1760.00

TEMPERATURE CONVERSION TABLE

CENTIGRADE TO FAHRENHEIT

TEMPERATURE FAHRENHEIT = 9/5 TEMPERATURE CENTIGRADE +32

C°	F°	C°	F°	C°	F°	C°	F°	C°	F°
−273	−459.4	185	365	435	815	770	1418	1270	2318
−250	−418	190	374	440	824	780	1436	1280	2336
−200	−328	195	383	445	833	790	1454	1290	2354
−175	−283	200	392	450	842	800	1472	1300	2372
−150	−238	205	401	455	851	810	1490	1310	2390
−125	−193	210	410	460	860	820	1508	1320	2408
−100	−148	215	419	465	869	830	1526	1330	2426
− 75	−103	220	428	470	878	840	1544	1340	2444
− 50	− 58	225	437	475	887	850	1562	1350	2462
− 40	− 40	230	446	480	896	860	1580	1360	2480
− 30	− 22	235	455	485	905	870	1598	1370	2498
− 20	− 4	240	464	490	914	880	1616	1380	2516
− 10	14	245	473	495	923	890	1634	1390	2534
0	32	250	482	500	932	900	1652	1400	2552
5	41	255	491	505	941	910	1670	1410	2570
10	50	260	500	510	950	920	1688	1420	2588
15	59	265	509	515	959	930	1706	1430	2606
20	68	270	518	520	968	940	1724	1440	2624
25	77	275	527	525	977	950	1742	1450	2642
30	86	280	536	530	986	960	1760	1460	2660
35	95	285	545	535	995	970	1778	1470	2678
40	104	290	554	540	1004	980	1796	1480	2696
45	113	295	563	545	1013	990	1814	1490	2714
50	122	300	572	550	1022	1000	1832	1500	2732
55	131	305	581	555	1031	1010	1850	1510	2750
60	140	310	590	560	1040	1020	1868	1520	2768
65	149	315	599	565	1049	1030	1886	1530	2786
70	158	320	608	570	1058	1040	1904	1540	2804
75	167	325	617	575	1067	1050	1922	1550	2822
80	176	330	626	580	1076	1060	1940	1560	2840
85	185	335	635	585	1085	1070	1958	1570	2858
90	194	340	644	590	1094	1080	1976	1580	2876
95	203	345	653	595	1103	1090	1994	1590	2894
100	212	350	662	600	1112	1100	2012	1600	2912
105	221	355	671	610	1130	1110	2030	1610	2930
110	230	360	680	620	1148	1120	2048	1620	2948
115	239	365	689	630	1166	1130	2066	1630	2966
120	248	370	698	640	1184	1140	2084	1640	2984
125	257	375	707	650	1202	1150	2102	1650	3002
130	266	380	716	660	1220	1160	2120	1660	3020
135	275	385	725	670	1238	1170	2138	1670	3038
140	284	390	734	680	1256	1180	2156	1680	3056
145	293	395	743	690	1274	1190	2174	1690	3074
150	302	400	752	700	1292	1200	2192	1700	3092
155	311	405	761	710	1310	1210	2210	1720	3128
160	320	410	770	720	1328	1220	2228	1740	3164
165	329	415	779	730	1346	1230	2246	1760	3200
170	338	420	788	740	1364	1240	2264	1780	3236
175	347	425	797	750	1382	1250	2282	1800	3272
180	356	430	806	760	1400	1260	2300	2000	3632

ATMOSPHERIC PRESSURE

Seven hundred and sixty (760) millimeters (29.92 inches) of mercury is generally accepted as a measure of the mean atmospheric pressure at sea level and called an atmosphere. The atmospheric pressure is generally expressed as 14.7 pounds per square inch.

The "metric atmosphere" is one kilogram per square centimeter and is in use in Continental Europe.

Equivalents of one atmosphere	760 millimeters of mercury 29.9212 inches of mercury 33.9007 feet of water 14.697 lbs. per sq. inch 1.033296 kilograms per sq. centimeter 1.033296 metric atmospheres

The pressure of the atmosphere in pounds per square inch and per square foot at various readings of the barometer may be found by the following rules:

Barometer in inches $\times$ 0.4916 = the pressure in pounds per square inch.

Pressure per square inch $\times$ 144 = the pressure in pounds per square foot.

Barometer ins.	Pres. per sq. in. lbs.	Pres. per sq. ft. lbs.
28.00	13.75	1980
28.25	13.88	1998
28.50	14.00	2016
28.75	14.12	2033
29.00	14.24	2051
29.25	14.37	2069
29.50	14.49	2086
29.75	14.61	2104
30.00	14.73	2122
30.25	14.86	2140
30.50	14.98	2157
30.75	15.10	2175
31.00	15.23	2193

METRIC SYSTEM

Since the metric system was first adopted in France, 1799, its use has become general throughout the world with the exception of the United States and Great Britain, although it is now legal in these countries. For scientific purposes the metric system is used almost exclusively.

The unit of length—the fundamental unit of the system—is the *meter,* which was legally established in the United States in 1866 as being equivalent to 39.37″.

The unit of weight is the *gram,* or 1/1000 of the weight of a liter of water at 4 °C.

The unit of capacity is the *liter,* whose volume equals that of a cube with sides of 1/10 meter.

All other units of the metric system are multiples or decimals of these three units and are designated by the prefixes:

Milli............meaning $\frac{1}{1000}$ or .001

Centi............meaning $\frac{1}{100}$ or .01

Deci............meaning $\frac{1}{10}$ or .1

Deka............meaning 10
Hecto............meaning 100
Kilo............meaning 1000

Following are tables of metric units and their corresponding English equivalents.

U. S. System | **Metrical System**

MEASURES OF LENGTH

U. S. System			Metrical System		
12 inches	=	1 foot	1 meter (m)	=	39.37 inches 3.2808 feet 1.0936 yards
3 feet	=	1 yard			
2 yards	=	1 fathom	1 centimeter (cm)	=	0.3937 inch
5½ yards	=	1 rod	1 millimeter (mm)	=	0.03937 inch
1760 yards 5280 feet 320 rods	=	1 statute mile	1 kilometer (km)	=	3280.8 feet 1093.6 yards 0.6214 statute mile
6080 feet	=	1 nautical mile	2.54 centimeters	=	1 inch
			0.3048 meter	=	1 foot
3 nautical miles	=	1 league	0.9144 meter	=	1 yard
			1.609 kilometers	=	1 statute mile

MEASURES OF SURFACE

U. S. System			Metrical System		
144 square inches	=	1 square foot	1 square meter	=	10.7638 sq. ft. 1.1959 sq. yds.
9 square feet	=	1 square yard			
30¼ square yards	=	1 square rod	1 sq. centimeter	=	0.155 sq. in.
43,560 square feet	=	1 acre	1 sq. millimeter	=	0.00155 sq. in.
640 acres	=	1 square mile	1 hectare	=	2.47 acres
			1 sq. kilometer	=	247.11 acres

6.45 sq. centimeters 645 sq. millimeters	=	1 sq. inch
0.0929 sq. meter	=	1 sq. foot
0.836 sq. meter	=	1 sq. yard
0.405 hectare	=	1 acre
2.5899 sq. kilometers	=	1 sq. mile

METRIC SYSTEM (Continued)

U. S. System | **Metrical System**

MEASURES OF VOLUME

Liquid Measures

U. S. System			Metrical System		
4 gills	=	1 pint	1 liter (lr) 1 cubic decimeter	=	1.057 U. S. liquid quarts 0.2642 U. S. liquid gallon 2.202 lbs. water at 62°F.
2 pints	=	1 quart			
4 quarts	=	1 gallon			
1 U. S. gallon	=	231 cu. in.			
1 British gallon	=	277.274 cu. in. 1.200 U. S. gal.			

Dry Measure

U. S. System			Metrical System		
2 pints	=	1 quart	1 liter	=	0.908 U. S. quart
8 quarts	=	1 peck	1.101 liters	=	1 U. S. quart
4 pecks	=	1 bushel			
1 Standard U. S. bushel	=	2150.42 cu. in. 1.2445 cu. ft.			
1 British Imperial bushel	=	2218.19 cu. in. 1.2837 cu. ft.			

CUBIC MEASURES

Cubic Measures

U. S. System			Metrical System		
1728 cubic inches	=	1 cubic foot	1 cubic meter	=	35.314 cu. ft. 1.308 cu. yds.
27 cubic feet	=	1 cubic yard	1 cubic centimeter 1 milliliter	=	0.061 cu. inch
			1 cubic decimeter	=	61.023 cu. in. 0.035 cu. foot

16.387 cu. centimeters	=	1 cubic inch
28.32 cu. decimeters 0.028 cubic meter	=	1 cubic foot
0.765 cubic meter	=	1 cubic yard

MEASURES OF WEIGHT

Avoirdupois

437.5 grains	=	1 ounce, oz.
1 ounce avoir.	=	0.912 troy ounce
16 ounces 7000 grains	=	1 pound, lb.
1 pound avoir.	=	1.217 troy pounds
28 pounds	=	1 quarter, qr.
4 quarters or 112 lbs.	=	1 hundredweight, cwt.
20 cwt. or 2240 lbs.	=	1 gross or long ton
2000 lbs.	=	1 net or short ton
2204.6 lbs.	=	1 metric ton

1 gram (gm)	=	15.432 grains 0.035 avoir. ounce 0.032 troy ounce
1 kilogram (kg)	=	2.2046 avoir. lb. 2.679 troy pounds
1000 kilograms or 1 metric ton	=	2204.6 pounds 0.984 long ton 1.102 short tons
0.065 gram	=	1 grain
28.35 grams	=	1 avoir. ounce
31.10 grams	=	1 troy ounce
0.454 kilogram	=	1 avoir. pound
0.373 kilogram	=	1 troy pound
1.016 metric tons	=	1 gross or long ton
0.907 metric ton	=	1 net or short ton

Apothecaries

20 grains	=	1 scruple
3 scruples	=	1 drachm
8 drachms	=	1 ounce 480 grains
12 ounces	=	1 pound 5760 grains

Troy

24 grains	=	1 pennyweight, dwt.
20 pennyweight or 480 grains	=	1 ounce, oz.
1 ounce troy	=	1.097 avoir. ounces
12 ounces or 5760 grains	=	1 pound, lb.
1 pound troy	=	0.822 avoir. pound

METRIC SYSTEM (Continued)

COMPOUND UNITS OF MEASURE

Metric to U. S. System

1 gram per sq. millimeter	=	1.422 lbs. per sq. inch
1 kilogram per sq. millimeter	=	1422.33 lbs. per sq. inch
1 kilogram per sq. centimeter	=	14.223 lbs. per sq. inch
1 gram per liter	=	0.06244 lb. per cubic foot 58.415 grains per U. S. gallon

U. S. to Metric System

1 pound per sq. inch	=	0.0703 kilogram per sq. centimeter
1 pound per sq. inch	=	0.703 gram per sq. millimeter
1 grain per U. S. gallon	=	0.017118 gram per liter 1.7118 parts per 100,000

Shipping Measure

40 cubic feet	=	1 U. S. shipping ton
42 cubic feet	=	1 British shipping ton

Circular Measure

60 seconds, ″	=	1 minute,
60 minutes, ′	=	1 degree, °
90 degrees, °	=	1 quadrant
4 quadrants or 360 degrees	=	1 circumference

MEASURES OF WORK, POWER AND HEAT

Foot-Pound: The unit of work or energy; equal to the work performed in raising one pound avoirdupois, one foot in height against the force of gravity.

1 kilogram-meter	=	7.233 foot-pounds
1 foot-pound	=	.1382 kilogram-meter

Horse Power: Measurement of the rate of work. The unit of horse power is 33,000 foot-pounds per minute, or 550 foot-pounds per second.

1 force de cheval	=	.9863 horse power

British Thermal Unit: (B.T.U.) is 1/180 of the amount of heat required to raise the temperature of one pound of water from 32°F. to 212°F. This heat unit is in general use in English speaking countries.

Calorie: (cal) is 1/100 of the heat required to raise the temperature of one gram of water from 0° to 100°C.

1 B.T.U.	=	0.252 calories
1 calorie	=	3.968 B.T.U.
1 B.T.U. per sq. foot	=	2.7126 calories per sq. meter
1 calorie per sq. meter	=	0.3686 B.T.U. per sq. foot

METRIC CONVERSION TABLE

MILLIMETERS TO INCHES   I METER = 39.37043196 INCHES

MM	0	100	200	300	400	500	600	700	800	900
0		3.937043	7.874086	11.811130	15.748173	19.685216	23.622259	27.559302	31.496346	35.433389
1	0.039370	3.976413	7.913451	11.850500	15.787543	19.724586	23.661629	27.598672	31.535716	35.472759
2	0.078740	4.015783	7.952821	11.889870	15.826913	19.763956	23.700999	27.638042	31.575086	35.512129
3	0.118110	4.055153	7.992191	11.929240	15.866283	19.803326	23.740369	27.677412	31.614456	35.551599
4	0.157480	4.094523	8.031561	11.968610	15.905653	19.842696	23.779739	27.716782	31.653826	35.590969
5	0.196850	4.133893	8.070931	12.007980	15.945023	19.882066	23.819109	27.756152	31.693196	35.630339
6	0.236220	4.173263	8.110301	12.047350	15.984393	19.921436	23.858479	27.795522	31.732566	35.669709
7	0.275590	4.212633	8.149671	12.086720	16.023763	19.960806	23.897849	27.834892	31.771936	35.709079
8	0.314960	4.252003	8.189041	12.126090	16.063133	20.000176	23.937219	27.874262	31.811306	35.748449
9	0.354330	4.291373	8.228411	12.165460	16.102503	20.039546	23.976589	27.913632	31.850676	35.787819
10	0.393704	4.330752	8.267791	12.204834	16.141877	20.078920	24.015963	27.953007	31.890049	35.827093
11	0.433074	4.370122	8.307161	12.244204	16.181247	20.118290	24.055333	27.992377	31.929419	35.866463
12	0.472444	4.409492	8.346531	12.283574	16.220617	20.157660	24.094703	28.031747	31.968789	35.905833
13	0.511814	4.448862	8.385901	12.322944	16.259987	20.197030	24.134073	28.071117	32.008159	35.945203
14	0.551184	4.488232	8.425271	12.362314	16.299357	20.236400	24.173443	28.110487	32.047529	35.984573
15	0.590554	4.527602	8.464641	12.401684	16.338727	20.275770	24.212813	28.149857	32.086899	36.023943
16	0.629924	4.566972	8.504011	12.441054	16.378097	20.315140	24.252183	28.189227	32.126269	36.063313
17	0.669294	4.606342	8.543381	12.480424	16.417467	20.354510	24.291553	28.228597	32.165639	36.102683
18	0.708664	4.645712	8.582751	12.519794	16.456837	20.393880	24.330923	28.267967	32.205009	36.142053
19	0.748034	4.685082	8.622121	12.559164	16.496207	20.433250	24.370293	28.307337	32.244379	36.181423
20	0.787409	4.724452	8.661495	12.598529	16.535591	20.472625	24.409668	28.346711	32.283754	36.220797
21	0.826779	4.763822	8.700865	12.637899	16.574961	20.511995	24.449038	28.386081	32.323124	36.260167
22	0.866149	4.803192	8.740235	12.677269	16.614331	20.551365	24.488408	28.425451	32.362494	36.299537
23	0.905519	4.842562	8.779605	12.716639	16.653701	20.590735	24.527778	28.464821	32.401864	36.338907
24	0.944889	4.881932	8.818975	12.756009	16.693071	20.630105	24.567148	28.504191	32.441234	36.378277
25	0.984259	4.921302	8.858345	12.795379	16.732441	20.669475	24.606518	28.543561	32.480604	36.417647
26	1.023629	4.960672	8.897715	12.834749	16.771811	20.708845	24.645888	28.582931	32.519974	36.457017
27	1.062999	5.000042	8.937085	12.874119	16.811181	20.748215	24.685258	28.622301	32.559344	36.496387
28	1.102369	5.039412	8.976455	12.913489	16.850551	20.787585	24.724628	28.661671	32.598714	36.535757
29	1.141739	5.078782	9.015825	12.952859	16.890121	20.826955	24.763998	28.701041	32.638084	36.575127
30	1.181113	5.118156	9.055199	12.992242	16.929286	20.866339	24.803372	28.740415	32.677458	36.614502
31	1.220483	5.157526	9.094569	13.031612	16.968656	20.905709	24.842742	28.779785	32.716828	36.653872
32	1.259853	5.196896	9.133939	13.070982	17.008026	20.945079	24.882112	28.819155	32.756198	36.693242
33	1.299223	5.236266	9.173309	13.110352	17.047396	20.984449	24.921482	28.858525	32.795568	36.732612
34	1.338593	5.275636	9.212679	13.149722	17.086766	21.023819	24.960852	28.897895	32.834938	36.771982
35	1.377963	5.315006	9.252049	13.189092	17.126136	21.063189	25.000222	28.937265	32.874308	36.811352
36	1.417333	5.354376	9.291419	13.228462	17.165506	21.102559	25.039592	28.976635	32.913678	36.850722
37	1.456703	5.393746	9.330789	13.267832	17.204876	21.141929	25.078962	29.016005	32.953048	36.890092
38	1.496073	5.433116	9.370159	13.307202	17.244246	21.181299	25.118332	29.055375	32.992418	36.929462
39	1.535443	5.472486	9.409529	13.346572	17.283616	21.220669	25.157702	29.094745	33.031788	36.968832
40	1.574817	5.511860	9.448904	13.385947	17.322990	21.260033	25.197076	29.134120	33.071163	37.008206
41	1.614187	5.551230	9.488274	13.425317	17.362360	21.299403	25.236446	29.173490	33.110533	37.047576
42	1.653557	5.590600	9.527644	13.464687	17.401730	21.338773	25.275816	29.212860	33.149903	37.086946
43	1.692927	5.629970	9.567014	13.504057	17.441100	21.378143	25.315186	29.252230	33.189273	37.126316
44	1.732297	5.669340	9.606384	13.543427	17.480470	21.417513	25.354556	29.291600	33.228643	37.165686
45	1.771667	5.708710	9.645754	13.582797	17.519840	21.456883	25.393926	29.330970	33.268013	37.205056
46	1.811037	5.748080	9.685124	13.622167	17.559210	21.496253	25.433296	29.370340	33.307383	37.244426
47	1.850407	5.787450	9.724494	13.661537	17.598580	21.535623	25.472666	29.409710	33.346753	37.283796
48	1.889777	5.826820	9.763864	13.700907	17.637950	21.574993	25.512036	29.449080	33.386123	37.323166
49	1.929147	5.866190	9.803234	13.740277	17.677320	21.614363	25.551406	29.488450	33.425493	37.362536

METRIC CONVERSION TABLE

MILLIMETERS TO INCHES 1 METER = 39.37043196 INCHES

MM	0	100	200	300	400	500	600	700	800	900
50	1.968522	5.905565	9.842609	13.779651	17.716694	21.653738	25.590781	29.527824	33.464867	37.401910
51	2.007892	5.944935	9.881979	13.819021	17.756064	21.693108	25.630151	29.567194	33.504237	37.441280
52	2.047262	5.984305	9.921349	13.858391	17.795434	21.732478	25.669521	29.606564	33.543607	37.480650
53	2.086632	6.023675	9.960719	13.897761	17.834804	21.771848	25.708891	29.645934	33.582977	37.520020
54	2.126002	6.063045	10.000089	13.937131	17.874174	21.811218	25.748261	29.685304	33.622347	37.559390
55	2.165372	6.102415	10.039459	13.976501	17.913544	21.850588	25.787631	29.724674	33.661717	37.598760
56	2.204742	6.141785	10.078829	14.015871	17.952914	21.889958	25.827001	29.764044	33.701087	37.638130
57	2.244112	6.181155	10.118199	14.055241	17.992284	21.929328	25.866371	29.803414	33.740457	37.677500
58	2.283482	6.220525	10.157569	14.094611	18.031654	21.968698	25.905741	29.842784	33.779827	37.716870
59	2.322852	6.259895	10.196939	14.133981	18.071024	22.008068	25.945111	29.882154	33.819197	37.756240
60	2.362226	6.299269	10.236312	14.173355	18.110399	22.047442	25.984485	29.921528	33.858571	37.795615
61	2.401596	6.338639	10.275682	14.212725	18.149769	22.086812	26.023855	29.960898	33.897941	37.834985
62	2.440966	6.378009	10.315052	14.252095	18.189139	22.126182	26.063225	30.000268	33.937311	37.874355
63	2.480336	6.417379	10.354422	14.291465	18.228509	22.165552	26.102595	30.039638	33.976681	37.913725
64	2.519706	6.456749	10.393792	14.330835	18.267879	22.204922	26.141965	30.079008	34.016051	37.953095
65	2.559076	6.496119	10.433162	14.370205	18.307249	22.244292	26.181335	30.118378	34.055421	37.992465
66	2.598446	6.535489	10.472532	14.409575	18.346619	22.283662	26.220705	30.157748	34.094791	38.031835
67	2.637816	6.574859	10.511902	14.448945	18.385989	22.323032	26.260075	30.197118	34.134161	38.071205
68	2.677186	6.614229	10.551272	14.488315	18.425359	22.362402	26.299445	30.236488	34.173531	38.110575
69	2.716556	6.653599	10.590642	14.527685	18.464729	22.401772	26.338815	30.275858	34.212901	38.149945
70	2.755930	6.692972	10.630017	14.567060	18.504103	22.441146	26.378189	30.315233	34.252276	38.189319
71	2.795300	6.732342	10.669387	14.606430	18.543473	22.480516	26.417559	30.354603	34.291646	38.228689
72	2.834670	6.771712	10.708757	14.645800	18.582843	22.519886	26.456929	30.393973	34.331016	38.268059
73	2.874040	6.811082	10.748127	14.685170	18.622213	22.559256	26.496299	30.433343	34.370386	38.307429
74	2.913410	6.850452	10.787497	14.724540	18.661583	22.598626	26.535669	30.472713	34.409756	38.346799
75	2.952780	6.889822	10.826867	14.763910	18.700953	22.637996	26.575039	30.512083	34.449126	38.386169
76	2.992150	6.929192	10.866237	14.803280	18.740323	22.677366	26.614409	30.551453	34.488496	38.425539
77	3.031520	6.968562	10.905607	14.842650	18.779693	22.716736	26.653779	30.590823	34.527866	38.464909
78	3.070890	7.007832	10.944977	14.882020	18.819063	22.756106	26.693149	30.630193	34.567236	38.504279
79	3.110260	7.047202	10.984347	14.921390	18.858433	22.795476	26.732519	30.669563	34.606606	38.543649
80	3.149635	7.086678	11.023721	14.960764	18.897807	22.834850	26.771894	30.708937	34.645980	38.583023
81	3.189005	7.126048	11.063091	15.000134	18.937177	22.874220	26.811264	30.748307	34.685350	38.622393
82	3.228375	7.165418	11.102461	15.039504	18.976547	22.913590	26.850634	30.787677	34.724720	38.661763
83	3.267745	7.204788	11.141831	15.078874	19.015917	22.952960	26.890004	30.827047	34.764090	38.701133
84	3.307115	7.244158	11.181201	15.118244	19.055287	22.992330	26.929374	30.866417	34.803460	38.740503
85	3.346485	7.283528	11.220571	15.157614	19.094657	23.031700	26.968744	30.905787	34.842830	38.779873
86	3.385855	7.322898	11.259941	15.196984	19.134027	23.071070	27.008114	30.945157	34.882200	38.819243
87	3.425225	7.362268	11.299311	15.236354	19.173397	23.110440	27.047484	30.984527	34.921570	38.858613
88	3.464595	7.401638	11.338681	15.275724	19.212767	23.149810	27.086854	31.023897	34.960940	38.897983
89	3.503965	7.441008	11.378051	15.315094	19.252137	23.189180	27.126224	31.063267	35.000310	38.937353
90	3.543339	7.480382	11.417425	15.354468	19.291512	23.228555	27.165598	31.102641	35.039684	38.976728
91	3.582709	7.519752	11.456795	15.393838	19.330882	23.267925	27.204968	31.142011	35.079054	39.016098
92	3.622079	7.559122	11.496165	15.433208	19.370252	23.307295	27.244338	31.181381	35.118424	39.055468
93	3.661449	7.598492	11.535535	15.472578	19.409622	23.346665	27.283708	31.220751	35.157794	39.094838
94	3.700819	7.637862	11.574905	15.511948	19.448992	23.386035	27.323078	31.260121	35.197164	39.134208
95	3.740189	7.677232	11.614275	15.551318	19.488362	23.424405	27.362448	31.299491	35.236534	39.173578
96	3.779559	7.716602	11.653645	15.590688	19.527732	23.463775	27.401818	31.338861	35.275904	39.212948
97	3.818929	7.755972	11.693015	15.630058	19.567102	23.503145	27.441188	31.378231	35.315274	39.252318
98	3.858299	7.795342	11.732385	15.669428	19.606472	23.542515	27.480558	31.417601	35.354644	39.291688
99	3.897669	7.834712	11.771755	15.708798	19.645842	23.581885	27.519928	31.456971	35.394014	39.331058
										39.370432

METRIC CONVERSION TABLES

Inches and Fractions of an Inch to Millimeters

9.37 Inches, U. S. Standard = 1 Meter = 100 Centimeters = 1000 Millimeters

Fractions	Inches 0	1	2	3	4	5	6	7	8	9	10	Fractions
0	0.00	25.40	50.80	76.20	101.60	127.00	152.40	177.80	203.20	228.60	254.00	0
1/64	0.40	25.80	51.20	76.60	102.00	127.40	152.80	178.20	203.60	229.00	254.40	1/64
1/32	0.79	26.19	51.59	76.99	102.39	127.79	153.19	178.59	203.99	229.39	254.79	1/32
3/64	1.19	26.59	51.99	77.39	102.79	128.19	153.59	178.99	204.39	229.79	255.19	3/64
1/16	1.59	26.99	52.39	77.79	103.19	128.59	153.99	179.39	204.79	230.19	255.59	1/16
5/64	1.98	27.38	52.79	78.18	103.58	128.98	154.38	179.78	205.18	230.58	255.99	5/64
3/32	2.38	27.78	53.18	78.58	103.98	129.38	154.78	180.18	205.58	230.98	256.38	3/32
7/64	2.78	28.18	53.58	78.98	104.38	129.78	155.18	180.58	205.98	231.38	256.78	7/64
1/8	3.18	28.58	53.98	79.38	104.78	130.18	155.58	180.98	206.38	231.78	257.18	1/8
9/64	3.57	28.97	54.37	79.77	105.17	130.57	155.97	181.37	206.77	232.17	257.57	9/64
5/32	3.97	29.37	54.77	80.17	105.57	130.97	156.37	181.77	207.17	232.57	257.97	5/32
11/64	4.37	29.77	55.17	80.57	105.97	131.37	156.77	182.17	207.57	232.97	258.37	11/64
3/16	4.76	30.16	55.56	80.96	106.36	131.76	157.16	182.56	207.96	233.36	258.76	3/16
13/64	5.16	30.56	55.96	81.36	106.76	132.16	157.56	182.96	208.36	233.76	259.16	13/64
7/32	5.56	30.96	56.36	81.76	107.16	132.56	157.96	183.36	208.76	234.16	259.56	7/32
15/64	5.95	31.35	56.75	82.15	107.55	132.95	158.35	183.75	209.15	234.55	259.95	15/64
1/4	6.35	31.75	57.15	82.55	107.95	133.35	158.75	184.15	209.55	234.95	260.35	1/4
17/64	6.75	32.15	57.55	82.95	108.35	133.75	159.15	184.55	209.95	235.35	260.75	17/64
9/32	7.14	32.54	57.94	83.34	108.74	134.14	159.54	184.94	210.34	235.74	261.14	9/32
19/64	7.54	32.94	58.34	83.74	109.14	134.54	159.94	185.34	210.74	236.14	261.54	19/64
5/16	7.94	33.34	58.74	84.14	109.54	134.94	160.34	185.74	211.14	236.54	261.94	5/16
21/64	8.33	33.73	59.13	84.53	109.93	135.33	160.73	186.13	211.53	236.93	262.34	21/64
11/32	8.73	34.13	59.53	84.93	110.33	135.73	161.13	186.53	211.93	237.33	262.73	11/32
23/64	9.13	34.53	59.93	85.33	110.73	136.13	161.53	186.93	212.33	237.73	263.13	23/64
3/8	9.53	34.93	60.33	85.73	111.13	136.53	161.93	187.33	212.73	238.13	263.53	3/8
25/64	9.92	35.32	60.72	86.12	111.52	136.92	162.32	187.72	213.12	238.52	263.92	25/64
13/32	10.32	35.72	61.12	86.52	111.92	137.32	162.72	188.12	213.52	238.92	264.32	13/32
27/64	10.72	36.12	61.52	86.92	112.32	137.72	163.12	188.52	213.92	239.32	264.72	27/64
7/16	11.11	36.51	61.91	87.31	112.71	138.11	163.51	188.91	214.31	239.71	265.11	7/16
29/64	11.51	36.91	62.31	87.71	113.11	138.51	163.91	189.31	214.71	240.11	265.51	29/64
15/32	11.91	37.31	62.71	88.11	113.51	138.91	164.31	189.71	215.11	240.51	265.91	15/32
31/64	12.30	37.70	63.10	88.50	113.90	139.30	164.70	190.10	215.50	240.90	266.30	31/64
1/2	12.70	38.10	63.50	88.90	114.30	139.70	165.10	190.50	215.90	241.30	266.70	1/2
33/64	13.10	38.50	63.90	89.30	114.70	140.10	165.50	190.90	216.30	241.70	267.10	33/64
17/32	13.49	38.89	64.29	89.69	115.09	140.49	165.89	191.29	216.69	242.09	267.49	17/32
35/64	13.89	39.29	64.69	90.09	115.49	140.89	166.29	191.69	217.09	242.49	267.89	35/64
9/16	14.29	39.69	65.09	90.49	115.89	141.29	166.69	192.09	217.49	242.89	268.29	9/16
37/64	14.68	40.08	65.48	90.88	116.28	141.68	167.08	192.48	217.88	243.28	268.69	37/64
19/32	15.08	40.48	65.88	91.28	116.68	142.08	167.48	192.88	218.28	243.68	269.08	19/32
39/64	15.48	40.88	66.28	91.68	117.08	142.48	167.88	193.28	218.68	244.08	269.48	39/64
5/8	15.88	41.28	66.68	92.08	117.48	142.88	168.28	193.68	219.08	244.48	269.88	5/8
41/64	16.27	41.67	67.07	92.47	117.87	143.27	168.67	194.07	219.47	244.87	270.27	41/64
21/32	16.67	42.07	67.47	92.87	118.27	143.67	169.07	194.47	219.87	245.27	270.67	21/32
43/64	17.07	42.47	67.87	93.27	118.67	144.07	169.47	194.87	220.27	245.67	271.07	43/64
11/16	17.46	42.86	68.26	93.66	119.06	144.46	169.86	195.26	220.66	246.06	271.46	11/16
45/64	17.86	43.26	68.66	94.06	119.46	144.86	170.26	195.66	221.06	246.46	271.86	45/64
23/32	18.26	43.66	69.06	94.46	119.86	145.26	170.66	196.06	221.46	246.86	272.26	23/32
47/64	18.65	44.05	69.45	94.85	120.25	145.65	171.05	196.45	221.85	247.25	272.65	47/64
3/4	19.05	44.45	69.85	95.25	120.65	146.05	171.45	196.85	222.25	247.65	273.05	3/4
49/64	19.45	44.85	70.25	95.65	121.05	146.45	171.85	197.25	222.65	248.05	273.45	49/64
25/32	19.84	45.24	70.64	96.04	121.44	146.85	172.24	197.64	223.04	248.44	273.84	25/32
51/64	20.24	45.64	71.04	96.44	121.84	147.24	172.64	198.04	223.44	248.84	274.24	51/64
13/16	20.64	46.04	71.44	96.84	122.24	147.64	173.04	198.44	223.84	249.24	274.64	13/16
53/64	21.03	46.43	71.83	97.23	122.63	148.03	173.43	198.83	224.23	249.64	275.04	53/64
27/32	21.43	46.83	72.23	97.63	123.03	148.43	173.83	199.23	224.63	250.03	275.43	27/32
55/64	21.83	47.23	72.63	98.03	123.43	148.83	174.23	199.63	225.03	250.43	275.83	55/64
7/8	22.23	47.63	73.03	98.43	123.83	149.23	174.63	200.03	225.43	250.83	276.23	7/8
57/64	22.62	48.02	73.42	98.82	124.22	149.62	175.02	200.42	225.82	251.22	276.62	57/64
29/32	23.02	48.42	73.82	99.22	124.62	150.02	175.42	200.82	226.22	251.62	277.02	29/32
59/64	23.42	48.82	74.22	99.62	125.02	150.42	175.82	201.22	226.62	252.02	277.42	59/64
15/16	23.81	49.21	74.61	100.01	125.41	150.81	176.21	201.61	227.01	252.41	277.81	15/16
61/64	24.21	49.61	75.01	100.41	125.81	151.21	176.61	202.01	227.41	252.81	278.21	61/64
31/32	24.61	50.01	75.41	100.81	126.21	151.61	177.01	202.41	227.81	253.21	278.61	31/32
63/64	25.00	50.40	75.80	101.20	126.60	152.00	177.40	202.80	228.20	253.60	279.00	63/64

METRIC CONVERSION TABLES (Continued)

Inches and Fractions of an Inch to Millimeters

39.37 Inches, U. S. Standard = 1 Meter = 100 Centimeters = 1000 Millimeter

Fractions	Inches 11	12	13	14	15	16	17	18	19	20	Fractions
0	279.40	304.80	330.20	355.60	381.00	406.40	431.80	457.20	482.60	508.00	0
1/64	279.80	305.20	330.60	356.00	381.40	406.80	432.20	457.60	483.00	508.40	1/64
1/32	280.19	305.59	330.99	356.39	381.79	407.19	432.59	457.99	483.39	508.80	1/32
3/64	280.59	305.99	331.39	356.79	382.19	407.59	432.99	458.39	483.79	509.19	3/64
1/16	280.99	306.39	331.79	357.19	382.59	407.99	433.39	458.79	484.19	509.59	1/16
5/64	281.39	306.79	332.19	357.59	382.99	408.39	433.79	459.19	484.59	509.99	5/64
3/32	281.78	307.18	332.58	357.98	383.38	408.78	434.18	459.58	484.98	510.38	3/32
7/64	282.18	307.58	332.98	358.38	383.78	409.18	434.58	459.98	485.38	510.78	7/64
1/8	282.58	307.98	333.38	358.78	384.18	409.58	434.98	460.38	485.78	511.18	1/8
9/64	282.97	308.37	333.77	359.17	384.57	409.97	435.37	460.77	486.17	511.57	9/64
5/32	283.37	308.77	334.17	359.57	384.97	410.37	435.77	461.17	486.57	511.97	5/32
11/64	283.77	309.17	334.57	359.97	385.37	410.77	436.17	461.57	486.97	512.37	11/64
3/16	284.16	309.56	334.96	360.36	385.76	411.16	436.56	461.96	487.36	512.76	3/16
13/64	284.56	309.96	335.36	360.76	386.16	411.56	436.96	462.36	487.76	513.16	13/64
7/32	284.96	310.36	335.76	361.16	386.56	411.96	437.36	462.76	488.16	513.56	7/32
15/64	285.35	310.75	336.15	361.55	386.95	412.35	437.75	463.15	488.55	513.95	15/64
1/4	285.75	311.15	336.55	361.95	387.35	412.75	438.15	463.55	488.95	514.35	1/4
17/64	286.15	311.55	336.95	362.35	387.75	413.15	438.55	463.95	489.35	514.75	17/64
9/32	286.54	311.94	337.34	362.74	388.14	413.54	438.95	464.34	489.74	515.15	9/32
19/64	286.94	312.34	337.74	363.14	388.54	413.94	439.34	464.74	490.14	515.54	19/64
5/16	287.34	312.74	338.14	363.54	388.94	414.34	439.74	465.14	490.54	515.94	5/16
21/64	287.74	313.14	338.54	363.94	389.34	414.74	440.14	465.54	490.94	516.34	21/64
11/32	288.13	313.53	338.93	364.33	389.73	415.13	440.53	465.93	491.33	516.73	11/32
23/64	288.53	313.93	339.33	364.73	390.13	415.53	440.93	466.33	491.73	517.13	23/64
3/8	288.93	314.33	339.73	365.13	390.53	415.93	441.33	466.73	492.13	517.53	3/8
25/64	289.32	314.72	340.12	365.52	390.92	416.32	441.72	467.12	492.52	517.92	25/64
13/32	289.72	315.12	340.52	365.92	391.32	416.72	442.12	467.52	492.92	518.32	13/32
27/64	290.12	315.52	340.92	366.32	391.72	417.12	442.52	467.92	493.32	518.72	27/64
7/16	290.51	315.91	341.31	366.71	392.11	417.51	442.91	468.31	493.71	519.11	7/16
29/64	290.91	316.31	341.71	367.11	392.51	417.91	443.31	468.71	494.11	519.51	29/64
15/32	291.31	316.71	342.11	367.51	392.91	418.31	443.71	469.11	494.51	519.91	15/32
31/64	291.70	317.10	342.50	367.90	393.30	418.70	444.10	469.50	494.90	520.30	31/64
1/2	292.10	317.50	342.90	368.30	393.70	419.10	444.50	469.90	495.30	520.70	1/2
33/64	292.50	317.90	343.30	368.70	394.10	419.50	444.90	470.30	495.70	521.10	33/64
17/32	292.89	318.29	343.70	369.09	394.50	419.89	445.29	470.69	496.10	521.50	17/32
35/64	293.29	318.69	344.09	369.49	394.89	420.29	445.69	471.09	496.49	521.89	35/64
9/16	293.69	319.09	344.49	369.89	395.29	420.69	446.09	471.49	496.89	522.29	9/16
37/64	294.09	319.49	344.89	370.29	395.69	421.09	446.49	471.89	497.29	522.69	37/64
19/32	294.48	319.88	345.28	370.68	396.08	421.48	446.88	472.28	497.68	523.08	19/32
39/64	294.88	320.28	345.68	371.08	396.48	421.88	447.28	472.68	498.08	523.48	39/64
5/8	295.28	320.68	346.08	371.48	396.88	422.28	447.68	473.08	498.48	523.88	5/8
41/64	295.67	321.07	346.47	371.87	397.27	422.67	448.07	473.47	498.87	524.27	41/64
21/32	296.07	321.47	346.87	372.27	397.67	423.07	448.47	473.87	499.27	524.67	21/32
43/64	296.47	321.87	347.27	372.67	398.07	423.47	448.87	474.27	499.67	525.07	43/64
11/16	296.86	322.26	347.66	373.06	398.46	423.86	449.26	474.66	500.06	525.46	11/16
45/64	297.26	322.66	348.06	373.46	398.86	424.26	449.66	475.06	500.46	525.86	45/64
23/32	297.66	323.06	348.46	373.86	399.26	424.66	450.06	475.46	500.86	526.26	23/32
47/64	298.05	323.45	348.85	374.25	399.65	425.06	450.45	475.85	501.25	526.65	47/64
3/4	298.45	323.85	349.25	374.65	400.05	425.45	450.85	476.25	501.65	527.05	3/4
49/64	298.85	324.25	349.65	375.05	400.45	425.85	451.25	476.65	502.05	527.45	49/64
25/32	299.24	324.64	350.04	375.44	400.84	426.25	451.64	477.04	502.45	527.85	25/32
51/64	299.64	325.04	350.44	375.84	401.24	426.64	452.04	477.44	502.84	528.24	51/64
13/16	300.04	325.44	350.84	376.24	401.64	427.04	452.44	477.84	503.24	528.64	13/16
53/64	300.44	325.84	351.24	376.64	402.04	427.44	452.84	478.24	503.64	529.04	53/64
27/32	300.83	326.23	351.63	377.03	402.43	427.83	453.23	478.63	504.03	529.43	27/32
55/64	301.23	326.63	352.03	377.43	402.83	428.23	453.63	479.03	504.43	529.83	55/64
7/8	301.63	327.03	352.43	377.83	403.23	428.63	454.03	479.43	504.83	530.23	7/8
57/64	302.02	327.42	352.82	378.22	403.62	429.02	454.42	479.82	505.22	530.62	57/64
29/32	302.42	327.82	353.22	378.62	404.02	429.42	454.82	480.22	505.62	531.02	29/32
59/64	302.82	328.22	353.62	379.02	404.42	429.82	455.22	480.62	506.02	531.42	59/64
15/16	303.21	328.61	354.01	379.41	404.81	430.21	455.61	481.01	506.41	531.81	15/16
61/64	303.61	329.01	354.41	379.81	405.21	430.61	456.01	481.41	506.81	532.21	61/64
31/32	304.01	329.41	354.81	380.21	405.61	431.01	456.41	481.81	507.21	532.61	31/32
63/64	304.40	329.80	355.20	380.60	406.00	431.40	456.80	482.20	507.60	533.00	63/64

METRIC CONVERSION TABLES (Continued)

Inches and Fractions of an Inch to Millimeters

39.37 Inches, U. S. Standard = 1 Meter = 100 Centimeters = 1000 Millimeters

Fractions	Inches										Fractions
	21	22	23	24	25	26	27	28	29	30	
0	533.40	558.80	584.20	609.60	635.00	660.40	685.80	711.20	736.60	762.00	0
1/64	533.80	559.20	584.60	610.00	635.40	660.80	686.20	711.60	737.00	762.40	1/64
1/32	534.20	559.60	585.00	610.40	635.80	661.20	686.60	712.00	737.40	762.80	1/32
3/64	534.59	559.99	585.39	610.79	636.19	661.59	686.99	712.39	737.79	763.19	3/64
1/16	534.99	560.39	585.79	611.19	636.59	661.99	687.39	712.79	738.19	763.59	1/16
5/64	535.39	560.79	586.19	611.59	636.99	662.39	687.79	713.19	738.59	763.99	5/64
3/32	535.78	561.18	586.58	611.98	637.38	662.78	688.18	713.58	738.98	764.38	3/32
7/64	536.18	561.58	586.98	612.38	637.78	663.18	688.58	713.98	739.38	764.78	7/64
1/8	536.58	561.98	587.38	612.78	638.18	663.58	688.98	714.38	739.78	765.18	1/8
9/64	536.97	562.37	587.77	613.17	638.57	663.97	689.37	714.77	740.17	765.57	9/64
5/32	537.37	562.77	588.17	613.57	638.97	664.37	689.77	715.17	740.57	765.97	5/32
11/64	537.77	563.17	588.57	613.97	639.37	664.77	690.17	715.57	740.97	766.37	11/64
3/16	538.16	563.56	588.96	614.36	639.76	665.16	690.56	715.96	741.36	766.76	3/16
13/64	538.56	563.96	589.36	614.76	640.16	665.56	690.96	716.36	741.76	767.16	13/64
7/32	538.96	564.36	589.76	615.16	640.56	665.96	691.36	716.76	742.16	767.56	7/32
15/64	539.35	564.75	590.15	615.55	640.95	666.35	691.75	717.15	742.55	767.96	15/64
1/4	539.75	565.15	590.55	615.95	641.35	666.75	692.15	717.55	742.95	768.35	1/4
17/64	540.15	565.55	590.95	616.35	641.75	667.15	692.55	717.95	743.35	768.75	17/64
9/32	540.55	565.95	591.35	616.75	642.15	667.55	692.95	718.35	743.75	769.15	9/32
19/64	540.94	566.34	591.74	617.14	642.54	667.94	693.34	718.74	744.14	769.54	19/64
5/16	541.34	566.74	592.14	617.54	642.94	668.34	693.74	719.14	744.54	769.94	5/16
21/64	541.74	567.14	592.54	617.94	643.34	668.74	694.14	719.54	744.94	770.34	21/64
11/32	542.13	567.53	592.93	618.33	643.73	669.13	694.53	719.93	745.33	770.73	11/32
23/64	542.53	567.93	593.33	618.73	644.13	669.53	694.93	720.33	745.73	771.13	23/64
3/8	542.93	568.33	593.73	619.13	644.53	669.93	695.33	720.73	746.13	771.53	3/8
25/64	543.32	568.72	594.12	619.52	644.92	670.32	695.72	721.12	746.52	771.92	25/64
13/32	543.72	569.12	594.52	619.92	645.32	670.72	696.12	721.52	746.92	772.32	13/32
27/64	544.12	569.52	594.92	620.32	645.72	671.12	696.52	721.92	747.32	772.72	27/64
7/16	544.51	569.91	595.31	620.71	646.11	671.51	696.91	722.31	747.71	773.11	7/16
29/64	544.91	570.31	595.71	621.11	646.51	671.91	697.31	722.71	748.11	773.51	29/64
15/32	545.31	570.71	596.11	621.51	646.91	672.31	697.71	723.11	748.51	773.91	15/32
31/64	545.70	571.10	596.50	621.90	647.30	672.70	698.10	723.50	748.91	774.31	31/64
1/2	546.10	571.50	596.90	622.30	647.70	673.10	698.50	723.90	749.30	774.70	1/2
33/64	546.50	571.90	597.30	622.70	648.10	673.50	698.90	724.30	749.70	775.10	33/64
17/32	546.90	572.30	597.70	623.10	648.50	673.90	699.30	724.70	750.10	775.50	17/32
35/64	547.29	572.69	598.09	623.49	648.89	674.29	699.69	725.09	750.49	775.89	35/64
9/16	547.69	573.09	598.49	623.89	649.29	674.69	700.09	725.49	750.89	776.29	9/16
37/64	548.09	573.49	598.89	624.29	649.69	675.09	700.49	725.89	751.29	776.69	37/64
19/32	548.48	573.88	599.28	624.68	650.08	675.48	700.88	726.28	751.68	777.08	19/32
39/64	548.88	574.28	599.68	625.08	650.48	675.88	701.28	726.68	752.08	777.48	39/64
5/8	549.28	574.68	600.08	625.48	650.88	676.28	701.68	727.08	752.48	777.88	5/8
41/64	549.67	575.07	600.47	625.87	651.27	676.67	702.07	727.47	752.87	778.27	41/64
21/32	550.07	575.47	600.87	626.27	651.67	677.07	702.47	727.87	753.27	778.67	21/32
43/64	550.47	575.87	601.27	626.67	652.07	677.47	702.87	728.27	753.67	779.07	43/64
11/16	550.86	576.26	601.66	627.06	652.46	677.86	703.26	728.66	754.06	779.46	11/16
45/64	551.26	576.66	602.06	627.46	652.86	678.26	703.66	729.06	754.46	779.86	45/64
23/32	551.66	577.06	602.46	627.86	653.26	678.66	704.06	729.46	754.86	780.26	23/32
47/64	552.05	577.45	602.85	628.25	653.65	679.05	704.45	729.85	755.26	780.66	47/64
3/4	552.45	577.85	603.25	628.65	654.05	679.45	704.85	730.25	755.65	781.05	3/4
49/64	552.85	578.25	603.65	629.05	654.45	679.85	705.25	730.65	756.05	781.45	49/64
25/32	553.25	578.65	604.05	629.45	654.85	680.25	705.65	731.05	756.45	781.85	25/32
51/64	553.64	579.04	604.44	629.84	655.24	680.64	706.04	731.44	756.84	782.24	51/64
13/16	554.04	579.44	604.84	630.24	655.64	681.04	706.44	731.84	757.24	782.64	13/16
53/64	554.44	579.84	605.24	630.64	656.04	681.44	706.84	732.24	757.64	783.04	53/64
27/32	554.83	580.23	605.63	631.03	656.43	681.83	707.23	732.63	758.03	783.43	27/32
55/64	555.23	580.63	606.03	631.43	656.83	682.23	707.63	733.03	758.43	783.83	55/64
7/8	555.63	581.03	606.43	631.83	657.23	682.63	708.03	733.43	758.83	784.23	7/8
57/64	556.02	581.42	606.82	632.22	657.62	683.02	708.42	733.82	759.22	784.62	57/64
29/32	556.42	581.82	607.22	632.62	658.02	683.42	708.82	734.22	759.62	785.02	29/32
59/64	556.82	582.22	607.62	633.02	658.42	683.82	709.22	734.62	760.02	785.42	59/64
15/16	557.21	582.61	608.01	633.41	658.81	684.21	709.61	735.01	760.41	785.81	15/16
61/64	557.61	583.01	608.41	633.81	659.21	684.61	710.01	735.41	760.81	786.21	61/64
31/32	558.01	583.41	608.81	634.21	659.61	685.01	710.41	735.81	761.21	786.61	31/32
63/64	558.40	583.80	609.20	634.60	660.00	685.40	710.80	736.20	761.61	787.01	63/64

METRIC CONVERSION TABLES (Continued)

Inches and Fractions of an Inch to Millimeters

39.37 Inches, U. S. Standard √1 Meter = 100 Centimeters = 1000 Millimeter

Fractions	Inches										Fractions
	31	32	33	34	35	36	37	38	39	40	
0	787.40	812.80	838.20	863.60	889.00	914.40	939.80	965.20	990.60	1016.00	0
1/64	787.80	813.20	838.60	864.00	889.40	914.80	940.20	965.60	991.00	1016.40	1/64
1/32	788.20	813.60	839.00	864.40	889.80	915.20	940.60	966.00	991.40	1016.80	1/32
3/64	788.59	813.99	839.39	864.79	890.19	915.59	940.99	966.39	991.79	1017.19	3/64
1/16	788.99	814.39	839.79	865.19	890.59	915.99	941.39	966.79	992.19	1017.59	1/16
5/64	789.39	814.79	840.19	865.59	890.99	916.39	941.79	967.19	992.59	1017.99	5/64
3/32	789.78	815.18	840.58	865.98	891.38	916.78	942.18	967.58	992.98	1018.38	3/32
7/64	790.18	815.58	840.98	866.38	891.78	917.18	942.58	967.98	993.38	1018.78	7/64
1/8	790.58	815.98	841.38	866.78	892.18	917.58	942.98	968.38	993.78	1019.18	1/8
9/64	790.97	816.37	841.77	867.17	892.57	917.97	943.37	968.77	994.17	1019.57	9/64
5/32	791.37	816.77	842.17	867.57	892.97	918.37	943.77	969.17	994.57	1019.97	5/32
11/64	791.77	817.17	842.57	867.97	893.37	918.77	944.17	969.57	994.97	1020.37	11/64
3/16	792.16	817.56	842.96	868.36	893.76	919.16	944.56	969.96	995.37	1020.77	3/16
13/64	792.56	817.96	843.36	868.76	894.16	919.56	944.96	970.36	995.76	1021.16	13/64
7/32	792.96	818.36	843.76	869.16	894.56	919.96	945.36	970.76	996.16	1021.56	7/32
15/64	793.36	818.76	844.16	869.56	894.96	920.36	945.76	971.16	996.56	1021.96	15/64
1/4	793.75	819.15	844.55	869.95	895.35	920.75	946.15	971.55	996.95	1022.35	1/4
17/64	794.15	819.55	844.95	870.35	895.75	921.15	946.55	971.95	997.35	1022.75	17/64
9/32	794.55	819.95	845.35	870.75	896.15	921.55	946.95	972.35	997.75	1023.15	9/32
19/64	794.94	820.34	845.74	871.14	896.54	921.94	947.34	972.74	998.14	1023.54	19/64
5/16	795.34	820.74	846.14	871.54	896.94	922.34	947.74	973.14	998.54	1023.94	5/16
21/64	795.74	821.14	846.54	871.94	897.34	922.74	948.14	973.54	998.94	1024.34	21/64
11/32	796.13	821.53	846.93	872.33	897.73	923.13	948.53	973.93	999.33	1024.73	11/32
23/64	796.53	821.93	847.33	872.73	898.13	923.53	948.93	974.33	999.73	1025.13	23/64
3/8	796.93	822.33	847.73	873.13	898.53	923.93	949.33	974.73	1000.13	1025.53	3/8
25/64	797.32	822.72	848.12	873.52	898.92	924.32	949.72	975.12	1000.52	1025.92	25/64
13/32	797.72	823.12	848.52	873.92	899.32	924.72	950.12	975.52	1000.92	1026.32	13/32
27/64	798.12	823.52	848.92	874.32	899.72	925.12	950.52	975.92	1001.32	1026.72	27/64
7/16	798.51	823.91	849.31	874.71	900.11	925.51	950.91	976.31	1001.72	1027.12	7/16
29/64	798.91	824.31	849.71	875.11	900.51	925.91	951.31	976.71	1002.11	1027.51	29/64
15/32	799.31	824.71	850.11	875.51	900.91	926.31	951.71	977.11	1002.51	1027.91	15/32
31/64	799.71	825.11	850.51	875.91	901.31	926.71	952.11	977.51	1002.91	1028.31	31/64
1/2	800.10	825.50	850.90	876.30	901.70	927.10	952.50	977.90	1003.30	1028.70	1/2
33/64	800.50	825.90	851.30	876.70	902.10	927.50	952.90	978.30	1003.70	1029.10	33/64
17/32	800.90	826.30	851.70	877.10	902.50	927.90	953.30	978.70	1004.10	1029.50	17/32
35/64	801.29	826.69	852.09	877.49	902.89	928.29	953.69	979.09	1004.49	1029.89	35/64
9/16	801.69	827.09	852.49	877.89	903.29	928.69	954.09	979.49	1004.89	1030.29	9/16
37/64	802.09	827.49	852.89	878.29	903.69	929.09	954.49	979.89	1005.29	1030.69	37/64
19/32	802.48	827.88	853.28	878.68	904.08	929.48	954.88	980.28	1005.68	1031.08	19/32
39/64	802.88	828.28	853.68	879.08	904.48	929.88	955.28	980.68	1006.08	1031.48	39/64
5/8	803.28	828.68	854.08	879.48	904.88	930.28	955.68	981.08	1006.48	1031.88	5/8
41/64	803.67	829.07	854.47	879.87	905.27	930.67	956.07	981.47	1006.87	1032.27	41/64
21/32	804.07	829.47	854.87	880.27	905.67	931.07	956.47	981.87	1007.27	1032.67	21/32
43/64	804.47	829.87	855.27	880.67	906.07	931.47	956.87	982.27	1007.67	1033.07	43/64
11/16	804.86	830.26	855.66	881.06	906.46	931.86	957.26	982.66	1008.07	1033.47	11/16
45/64	805.26	830.66	856.06	881.46	906.86	932.26	957.66	983.06	1008.46	1033.86	45/64
23/32	805.66	831.06	856.46	881.86	907.26	932.66	958.06	983.46	1008.86	1034.26	23/32
47/64	806.06	831.46	856.86	882.26	907.66	933.06	958.46	983.86	1009.26	1034.66	47/64
3/4	806.45	831.85	857.25	882.65	908.05	933.45	958.85	984.25	1009.65	1035.05	3/4
49/64	806.85	832.25	857.65	883.05	908.45	933.85	959.25	984.65	1010.05	1035.45	49/64
25/32	807.25	832.65	858.05	883.45	908.85	934.25	959.65	985.05	1010.45	1035.85	25/32
51/64	807.64	833.04	858.44	883.84	909.24	934.64	960.04	985.44	1010.84	1036.24	51/64
13/16	808.04	833.44	858.84	884.24	909.64	935.04	960.44	985.84	1011.24	1036.64	13/16
53/64	808.44	833.84	859.24	884.64	910.04	935.44	960.84	986.24	1011.64	1037.04	53/64
27/32	808.83	834.23	859.63	885.03	910.43	935.83	961.23	986.63	1012.03	1037.43	27/32
55/64	809.23	834.63	860.03	885.43	910.83	936.23	961.63	987.03	1012.43	1037.83	55/64
7/8	809.63	835.03	860.43	885.83	911.23	936.63	962.03	987.43	1012.83	1038.23	7/8
57/64	810.02	835.42	860.82	886.22	911.62	937.02	962.42	987.82	1013.22	1038.62	57/64
29/32	810.42	835.82	861.22	886.62	912.02	937.42	962.82	988.22	1013.62	1039.02	29/32
59/64	810.82	836.22	861.62	887.02	912.42	937.82	963.22	988.62	1014.02	1039.42	59/64
15/16	811.21	836.61	862.01	887.41	912.81	938.21	963.61	989.01	1014.42	1039.82	15/16
61/64	811.61	837.01	862.41	887.81	913.21	938.61	964.01	989.41	1014.81	1040.21	61/64
31/32	812.01	837.41	862.81	888.21	913.61	939.01	964.41	989.81	1015.21	1040.61	31/32
63/64	812.41	837.81	863.21	888.61	914.01	939.41	964.81	990.21	1015.61	1041.01	63/64

METRIC CONVERSION TABLES

Inches to Centimeters—1 in. = 2.540005 cm

In.	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	2.540	5.080	7.620	10.160	12.700	15.240	17.780	20.320	22.860
1	25.400	27.940	30.480	33.020	35.560	38.100	40.640	43.180	45.720	48.260
2	50.800	53.340	55.880	58.420	60.960	63.500	66.040	68.580	71.120	73.660
3	76.200	78.740	81.280	83.820	86.360	88.900	91.440	93.980	96.520	99.060
4	101.600	104.140	106.680	109.220	111.760	114.300	116.840	119.380	121.920	124.460
5	127.000	129.540	132.080	134.620	137.160	139.700	142.240	144.780	147.320	149.860
6	152.400	154.940	157.480	160.020	162.560	165.100	167.640	170.180	172.720	175.260
7	177.800	180.340	182.880	185.420	187.960	190.500	193.040	195.580	198.120	200.660
8	203.200	205.740	208.280	210.820	213.360	215.900	218.440	220.980	223.520	226.060
9	228.600	231.140	233.680	236.220	238.760	241.300	243.840	246.380	248.920	251.460

INCHES^2 TO CENTIMETERS^2—1 in.^{2} = 6.451625 cm^2

In.^{2}	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	6.452	12.903	19.355	25.807	32.258	38.710	45.161	51.613	58.065
1	64.516	70.968	77.420	83.871	90.323	96.774	103.226	109.678	116.129	122.581
2	129.033	135.484	141.936	148.387	154.839	161.291	167.742	174.194	180.646	187.097
3	193.549	200.000	206.452	212.904	219.355	225.807	232.259	238.710	245.162	251.613
4	258.065	264.517	270.968	277.420	283.872	290.323	296.775	303.226	309.678	316.130
5	322.581	329.033	335.485	341.936	348.388	354.839	361.291	367.743	374.194	380.646
6	387.098	393.549	400.001	406.452	412.904	419.356	425.807	432.259	438.711	445.162
7	451.614	458.065	464.517	470.969	477.420	483.872	490.324	496.775	503.227	509.678
8	516.130	522.582	529.033	535.485	541.937	548.388	554.840	561.291	567.743	574.195
9	580.646	587.098	593.550	600.001	606.453	612.904	619.356	625.808	632.259	638.711

INCHES^3 TO CENTIMETERS^3—1 in.^{3} = 16.38716 cm^3

In.^{3}	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	16.39	32.77	49.16	65.55	81.94	98.32	114.71	131.10	147.48
1	163.87	180.26	196.65	213.03	229.42	245.81	262.19	278.58	294.97	311.36
2	327.74	344.13	360.52	376.90	393.29	409.68	426.07	442.45	458.84	475.23
3	491.61	508.00	524.39	540.78	557.16	573.55	589.94	606.32	622.71	639.10
4	655.49	671.87	688.26	704.65	721.04	737.42	753.81	770.20	786.58	802.97
5	819.36	835.75	852.13	868.52	884.91	901.29	917.68	934.07	950.46	966.84
6	983.23	999.62	1016.00	1032.39	1048.78	1065.17	1081.55	1097.94	1114.33	1130.71
7	1147.10	1163.49	1179.88	1196.26	1212.65	1229.04	1245.42	1261.81	1278.20	1294.59
8	1310.97	1327.36	1343.75	1360.13	1376.52	1392.91	1409.30	1425.68	1442.07	1458.46
9	1474.84	1491.23	1507.62	1524.01	1540.39	1556.78	1573.17	1589.55	1605.94	1622.33

INCHES^4 TO CENTIMETERS^4—1 in.^{4} = 41.62347 cm^4

In.^{4}	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	41.62	83.25	124.87	166.49	208.12	249.74	291.36	332.99	374.61
1	416.23	457.86	499.48	541.11	582.73	624.35	665.98	707.60	749.22	790.85
2	832.47	874.09	915.72	957.34	998.96	1040.59	1082.21	1123.83	1165.46	1207.08
3	1248.70	1290.33	1331.95	1373.57	1415.20	1456.82	1498.44	1540.07	1581.69	1623.32
4	1664.94	1706.56	1748.19	1789.81	1831.43	1873.06	1914.68	1956.30	1997.93	2039.55
5	2081.17	2122.80	2164.42	2206.04	2247.67	2289.29	2330.91	2372.54	2414.16	2455.78
6	2497.41	2539.03	2580.66	2622.28	2663.90	2705.53	2747.15	2788.77	2830.40	2872.02
7	2913.64	2955.27	2996.89	3038.51	3080.14	3121.76	3163.38	3205.01	3246.63	3288.25
8	3329.88	3371.50	3413.12	3454.75	3496.37	3537.99	3579.62	3621.24	3662.87	3704.49
9	3746.11	3787.74	3829.36	3870.98	3912.61	3954.23	3995.85	4037.48	4079.10	4120.72

METRIC CONVERSION TABLES

Centimeters to Inches—1 cm = 0.3937 in.

cm	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.3937	0.7874	1.1811	1.5748	1.9685	2.3622	2.7559	3.1496	3.5433
1	3.9370	4.3307	4.7244	5.1181	5.5118	5.9055	6.2992	6.6929	7.0866	7.4803
2	7.8740	8.2677	8.6614	9.0551	9.4488	9.8425	10.2362	10.6299	11.0236	11.4173
3	11.8110	12.2047	12.5984	12.9921	13.3858	13.7795	14.1732	14.5669	14.9606	15.3543
4	15.7480	16.1417	16.5354	16.9291	17.3228	17.7165	18.1102	18.5039	18.8976	19.2913
5	19.6850	20.0787	20.4724	20.8661	21.2598	21.6535	22.0472	22.4409	22.8346	23.2283
6	23.6220	24.0157	24.4094	24.8031	25.1968	25.5905	25.9842	26.3779	26.7716	27.1653
7	27.5590	27.9527	28.3464	28.7401	29.1338	29.5275	29.9212	30.3149	30.7086	31.1023
8	31.4960	31.8897	32.2834	32.6771	33.0708	33.4645	33.8582	34.2519	34.6456	35.0393
9	35.4330	35.8267	36.2204	36.6141	37.0078	37.4015	37.7952	38.1889	38.5826	38.9763

CENTIMETERS^2 TO INCHES^2—1 cm^2 = 0.15499969 in.^{2}

cm^2	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.1550	0.3100	0.4650	0.6200	0.7750	0.9300	1.0850	1.2400	1.3950
1	1.5500	1.7050	1.8600	2.0150	2.1700	2.3250	2.4800	2.6350	2.7900	2.9450
2	3.1000	3.2550	3.4100	3.5650	3.7200	3.8750	4.0300	4.1850	4.3400	4.4950
3	4.6500	4.8050	4.9600	5.1150	5.2700	5.4250	5.5800	5.7350	5.8900	6.0450
4	6.2000	6.3550	6.5100	6.6650	6.8200	6.9750	7.1300	7.2850	7.4400	7.5950
5	7.7500	7.9050	8.0600	8.2150	8.3700	8.5250	8.6800	8.8350	8.9900	9.1450
6	9.3000	9.4550	9.6100	9.7650	9.9200	10.0750	10.2300	10.3850	10.5400	10.6950
7	10.8500	11.0050	11.1600	11.3150	11.4700	11.6250	11.7800	11.9350	12.0900	12.2450
8	12.4000	12.5550	12.7100	12.8650	13.0200	13.1750	13.3300	13.4850	13.6400	13.7950
9	13.9500	14.1050	14.2600	14.4150	14.5700	14.7250	14.8800	15.0350	15.1900	15.3450

CENTIMETERS^3 TO INCHES^3—1 cm^3 = 0.0610234 in.^{3}

cm^3	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.06102	0.12205	0.18307	0.24409	0.30512	0.36614	0.42716	0.48819	0.54921
1	0.61023	0.67126	0.73228	0.79330	0.85433	0.91535	0.97637	1.03740	1.09842	1.15944
2	1.22047	1.28149	1.34251	1.40354	1.46456	1.52559	1.58661	1.64763	1.70866	1.76968
3	1.83070	1.89173	1.95275	2.01377	2.07480	2.13582	2.19684	2.25787	2.31889	2.37991
4	2.44094	2.50196	2.56298	2.62401	2.68503	2.74605	2.80708	2.86810	2.92912	2.99015
5	3.05117	3.11219	3.17322	3.23424	3.29526	3.35629	3.41731	3.47833	3.53936	3.60038
6	3.66140	3.72243	3.78345	3.84447	3.90550	3.96652	4.02754	4.08857	4.14959	4.21061
7	4.27164	4.33266	4.39368	4.45471	4.51573	4.57675	4.63778	4.69880	4.75983	4.82085
8	4.88187	4.94290	5.00392	5.06494	5.12597	5.18699	5.24801	5.30904	5.37006	5.43108
9	5.49211	5.55313	5.61415	5.67518	5.73620	5.79722	5.85825	5.91927	5.98029	6.04132

CENTIMETERS^4 TO INCHES^4—1 cm^4 = 0.0240249 in.^{4}

cm^4	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.02402	0.04805	0.07207	0.09610	0.12012	0.14415	0.16817	0.19220	0.21622
1	0.24025	0.26427	0.28830	0.31232	0.33635	0.36037	0.38440	0.40842	0.43245	0.45647
2	0.48050	0.50452	0.52855	0.55257	0.57660	0.60062	0.62465	0.64867	0.67270	0.69672
3	0.72075	0.74477	0.76880	0.79282	0.81685	0.84087	0.86490	0.88892	0.91295	0.93697
4	0.96100	0.98502	1.00905	1.03307	1.05710	1.08112	1.10515	1.12917	1.15320	1.17722
5	1.20125	1.22527	1.24930	1.27332	1.29734	1.32137	1.34539	1.36942	1.39344	1.41747
6	1.44149	1.46552	1.48954	1.51357	1.53759	1.56162	1.58564	1.60967	1.63369	1.65772
7	1.68174	1.70577	1.72979	1.75382	1.77784	1.80187	1.82589	1.84992	1.87394	1.89797
8	1.92199	1.94602	1.97004	1.99407	2.01809	2.04212	2.06614	2.09017	2.11419	2.13822
9	2.16224	2.18627	2.21029	2.23432	2.25834	2.28237	2.30639	2.33042	2.35444	2.37847

METRIC CONVERSION TABLES

Feet to Meters = 1 ft. = 0.3048006 m

Ft. Tens	Units 0	1	2	3	4	5	6	7	8	9
0	....	0.3048	0.6096	0.9144	1.2192	1.5240	1.8288	2.1336	2.4384	2.7432
1	3.0480	3.3528	3.6576	3.9624	4.2672	4.5720	4.8768	5.1816	5.4864	5.7912
2	6.0960	6.4008	6.7056	7.0104	7.3152	7.6200	7.9248	8.2296	8.5344	8.8392
3	9.1440	9.4488	9.7536	10.0584	10.3632	10.6680	10.9728	11.2776	11.5824	11.8872
4	12.1920	12.4968	12.8016	13.1064	13.4112	13.7160	14.0208	14.3256	14.6304	14.9352
5	15.2400	15.5448	15.8496	16.1544	16.4592	16.7640	17.0688	17.3736	17.6784	17.9832
6	18.2880	18.5928	18.8976	19.2024	19.5072	19.8120	20.1168	20.4216	20.7264	21.0312
7	21.3360	21.6408	21.9456	22.2504	22.5552	22.8600	23.1648	23.4696	23.7744	24.0792
8	24.3840	24.6888	24.9936	25.2984	25.6033	25.9081	26.2129	26.5177	26.8225	27.1273
9	27.4321	27.7369	28.0417	28.3465	28.6513	28.9561	29.2609	29.5657	29.8705	30.1753

YARDS TO METERS—1 yd. = 0.9144018 m

Yds. Tens	Units 0	1	2	3	4	5	6	7	8	9
0	....	0.9144	1.8288	2.7432	3.6576	4.5720	5.4864	6.4008	7.3152	8.2296
1	9.1440	10.0584	10.9728	11.8872	12.8016	13.7160	14.6304	15.5448	16.4592	17.3736
2	18.2880	19.2024	20.1168	21.0312	21.9456	22.8600	23.7744	24.6888	25.6033	26.5177
3	27.4321	28.3465	29.2609	30.1753	31.0897	32.0041	32.9185	33.8329	34.7473	35.6617
4	36.5761	37.4905	38.4049	39.3193	40.2337	41.1481	42.0625	42.9769	43.8913	44.8057
5	45.7201	46.6345	47.5489	48.4633	49.3777	50.2921	51.2065	52.1209	53.0353	53.9497
6	54.8641	55.7785	56.6929	57.6073	58.5217	59.4361	60.3505	61.2649	62.1793	63.0937
7	64.0081	64.9225	65.8369	66.7513	67.6657	68.5801	69.4945	70.4089	71.3233	72.2377
8	73.1521	74.0665	74.9809	75.8953	76.8098	77.7242	78.6386	79.5530	80.4674	81.3818
9	82.2962	83.2106	84.1250	85.0394	85.9538	86.8682	87.7826	88.6970	89.6114	90.5258

POUNDS PER FOOT TO KILOGRAMS PER METER—1 lb./ft. = 1.488161 kg/m

Lb./Ft. Tens	Units 0	1	2	3	4	5	6	7	8	9
0	....	1.488	2.976	4.464	5.953	7.441	8.929	10.417	11.905	13.393
1	14.882	16.370	17.858	19.346	20.834	22.322	23.811	25.299	26.787	28.275
2	29.763	31.251	32.740	34.228	35.716	37.204	38.692	40.180	41.669	43.157
3	44.645	46.133	47.621	49.109	50.597	52.086	53.574	55.062	56.550	58.038
4	59.526	61.015	62.503	63.991	65.479	66.967	68.455	69.944	71.432	72.920
5	74.408	75.896	77.384	78.873	80.361	81.849	83.337	84.825	86.313	87.801
6	89.290	90.778	92.266	93.754	95.242	96.730	98.219	99.707	101.195	102.683
7	104.171	105.659	107.148	108.636	110.124	111.612	113.100	114.588	116.077	117.565
8	119.053	120.541	122.029	123.517	125.006	126.494	127.982	129.470	130.958	132.446
9	133.934	135.423	136.911	138.399	139.887	141.375	142.863	144.352	145.840	147.328

POUNDS PER YARD TO KILOGRAMS PER METER—1 lb./yd. = 0.496053 kg/m

Lb./Ft. Tens	Units 0	1	2	3	4	5	6	7	8	9
0	....	0.4961	0.9921	1.4882	1.9842	2.4803	2.9763	3.4724	3.9684	4.4645
1	4.9605	5.4566	5.9526	6.4487	6.9447	7.4408	7.9368	8.4329	8.9290	9.4250
2	9.9211	10.4171	10.9132	11.4092	11.9053	12.4013	12.8974	13.3934	13.8895	14.3855
3	14.8816	15.3776	15.8737	16.3697	16.8658	17.3619	17.8579	18.3540	18.8500	19.3461
4	19.8421	20.3382	20.8342	21.3303	21.8263	22.3224	22.8184	23.3145	23.8105	24.3066
5	24.8027	25.2987	25.7948	26.2908	26.7869	27.2829	27.7790	28.2750	28.7711	29.2671
6	29.7632	30.2592	30.7553	31.2513	31.7474	32.2434	32.7395	33.2356	33.7316	34.2277
7	34.7237	35.2198	35.7158	36.2119	36.7079	37.2040	37.7000	38.1961	38.6921	39.1882
8	39.6842	40.1803	40.6763	41.1724	41.6685	42.1645	42.6606	43.1566	43.6527	44.1487
9	44.6448	45.1408	45.6369	46.1329	46.6290	47.1250	47.6211	48.1171	48.6132	49.1092

METRIC CONVERSION TABLES

Meters to Feet—1 m = 3.2808333 ft.

m	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	3.281	6.562	9.843	13.123	16.404	19.685	22.966	26.247	29.528
1	32.808	36.089	39.370	42.651	45.932	49.213	52.493	55.774	59.055	62.336
2	65.617	68.898	72.178	75.459	78.740	82.021	85.302	88.583	91.863	95.144
3	98.425	101.706	104.987	108.268	111.548	114.829	118.110	121.391	124.672	127.953
4	131.233	134.514	137.795	141.076	144.357	147.638	150.918	154.199	157.480	160.761
5	164.042	167.323	170.603	173.884	177.165	180.446	183.727	187.008	190.288	193.569
6	196.850	200.131	203.412	206.693	209.973	213.254	216.535	219.816	223.097	226.378
7	229.658	232.939	236.220	239.501	242.782	246.063	249.343	252.624	255.905	259.186
8	262.467	265.748	269.028	272.309	275.590	278.871	282.152	285.433	288.713	291.994
9	295.275	298.556	301.837	305.118	308.398	311.679	314.960	318.241	321.522	324.803

METERS TO YARDS—1 m = 1.0936111 yd.

m	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	1.094	2.187	3.281	4.374	5.468	6.562	7.655	8.749	9.842
1	10.936	12.030	13.123	14.217	15.311	16.404	17.498	18.591	19.685	20.779
2	21.872	22.966	24.059	25.153	26.247	27.340	28.434	29.527	30.621	31.715
3	32.808	33.902	34.996	36.089	37.183	38.276	39.370	40.464	41.557	42.651
4	43.744	44.838	45.932	47.025	48.119	49.212	50.306	51.400	52.493	53.587
5	54.681	55.774	56.868	57.961	59.055	60.149	61.242	62.336	63.429	64.523
6	65.617	66.710	67.804	68.897	69.991	71.085	72.178	73.272	74.366	75.459
7	76.553	77.646	78.740	79.834	80.927	82.021	83.114	84.208	85.302	86.395
8	87.489	88.582	89.676	90.770	91.863	92.957	94.051	95.144	96.238	97.331
9	98.425	99.519	100.612	101.706	102.799	103.893	104.987	106.080	107.174	108.267

KILOGRAMS PER METER TO POUNDS PER FOOT—1 kg/m = 0.67197 lb./ft.

kg/m	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.6720	1.3439	2.0159	2.6879	3.3599	4.0318	4.7038	5.3758	6.0477
1	6.7197	7.3917	8.0636	8.7356	9.4076	10.0796	10.7515	11.4235	12.0955	12.7674
2	13.4394	14.1114	14.7833	15.4553	16.1273	16.7993	17.4712	18.1432	18.8152	19.4871
3	20.1591	20.8311	21.5030	22.1750	22.8470	23.5190	24.1909	24.8629	25.5349	26.2068
4	26.8788	27.5508	28.2227	28.8947	29.5667	30.2387	30.9106	31.5826	32.2546	32.9265
5	33.5985	34.2705	34.9424	35.6144	36.2864	36.9584	37.6303	38.3023	38.9743	39.6462
6	40.3182	40.9902	41.6621	42.3341	43.0061	43.6781	44.3500	45.0220	45.6940	46.3659
7	47.0379	47.7099	48.3818	49.0538	49.7258	50.3978	51.0697	51.7417	52.4137	53.0856
8	53.7576	54.4296	55.1015	57.7735	56.4455	57.1175	57.7894	58.4614	59.1334	59.8053
9	60.4773	61.1493	61.8212	62.4932	63.1652	63.8372	64.5091	65.1811	65.8531	66.5250

KILOGRAMS PER METER TO POUNDS PER YARD—1 kg/m = 2.015913 lb./yd.

kg/m	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	2.016	4.032	6.048	8.064	10.080	12.095	14.111	16.127	18.143
1	20.159	22.175	24.191	26.207	28.223	30.239	32.255	34.271	36.286	38.302
2	40.318	42.334	44.350	46.366	48.382	50.398	52.414	54.430	56.446	58.461
3	60.477	62.493	64.509	66.525	68.541	70.557	72.573	74.589	76.605	78.621
4	80.637	82.652	84.668	86.684	88.700	90.716	92.732	94.748	96.764	98.780
5	100.796	102.812	104.827	106.843	108.859	110.875	112.891	114.907	116.923	118.939
6	120.955	122.971	124.987	127.003	129.018	131.034	133.050	135.066	137.082	139.098
7	141.114	143.130	145.146	147.162	149.178	151.193	153.209	155.225	157.241	159.257
8	161.273	163.289	165.305	167.321	169.337	171.353	173.369	175.384	177.400	179.416
9	181.432	183.448	185.464	187.480	189.496	191.512	193.528	195.544	197.559	199.575

METRIC CONVERSION TABLES

Pounds per sq. in. to kg per sq. cm—1 lb./in.^{2} = 0.0703067 kg/cm^2

Lb./In.^{2}	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.07031	0.14061	0.21092	0.28123	0.35153	0.42184	0.49215	0.56245	0.63276
1	0.70307	0.77337	0.84368	0.91399	0.98429	1.05460	1.12491	1.19521	1.26552	1.33583
2	1.40613	1.47644	1.54675	1.61705	1.68736	1.75767	1.82797	1.89828	1.96859	2.03889
3	2.10920	2.17951	2.24981	2.32012	2.39043	2.46073	2.53104	2.60135	2.67165	2.74196
4	2.81227	2.88257	2.95288	3.02319	3.09349	3.16380	3.23411	3.30441	3.37472	3.44503
5	3.51534	3.58564	3.65595	3.72626	3.79656	3.86687	3.93718	4.00748	4.07779	4.14810
6	4.21840	4.28871	4.35902	4.42932	4.49963	4.56994	4.64024	4.71055	4.78086	4.85116
7	4.92147	4.99178	5.06208	5.13239	5.20270	5.27300	5.34331	5.41362	5.48392	5.55423
8	5.62454	5.69484	5.76515	5.83546	5.90576	5.97607	6.04638	6.11668	6.18699	6.25730
9	6.32760	6.39791	6.46822	6.53852	6.60883	6.67914	6.74944	6.81975	6.89006	6.96036

KG PER SQ. CM TO POUNDS PER SQ. IN.—1 kg/cm^2 = 14.2234 lbs./in.^{2}

kg/cm^2	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	14.22	28.45	42.67	56.89	71.12	85.34	99.56	113.79	128.01
1	142.23	156.46	170.68	184.90	199.13	213.35	227.57	241.80	256.02	270.24
2	284.47	298.69	312.91	327.14	341.36	355.59	369.81	384.03	398.26	412.48
3	426.70	440.93	455.15	469.37	483.60	497.82	512.04	526.27	540.49	554.71
4	568.94	583.16	597.38	611.61	625.83	640.05	654.28	668.50	682.72	696.95
5	711.17	725.39	739.62	753.84	768.06	782.29	796.51	810.73	824.96	839.18
6	853.40	867.63	881.85	896.07	910.30	924.52	938.74	952.97	967.19	981.41
7	995.64	1009.86	1024.08	1038.31	1052.53	1066.76	1080.98	1095.20	1109.43	1123.65
8	1137.87	1152.10	1166.32	1180.54	1194.77	1208.99	1223.21	1237.44	1251.66	1265.88
9	1280.11	1294.33	1308.55	1322.78	1337.00	1351.22	1365.45	1379.67	1393.89	1408.12

INCH-POUNDS TO KILOGRAM-CENTIMETERS—1 in.-lb. = 1.152127 kg-cm

In. Lbs.	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	1.152	2.304	3.456	4.609	5.761	6.913	8.065	9.217	10.369
1	11.521	12.673	13.826	14.978	16.130	17.282	18.434	19.586	20.738	21.890
2	23.043	24.195	25.347	26.499	27.651	28.803	29.955	31.107	32.260	33.412
3	34.564	35.716	36.868	38.020	39.172	40.324	41.477	42.629	43.781	44.933
4	46.085	47.237	48.389	49.541	50.694	51.846	52.998	54.150	55.302	56.454
5	57.606	58.758	59.911	61.063	62.215	63.367	64.519	65.671	66.823	67.975
6	69.128	70.280	71.432	72.584	73.736	74.888	76.040	77.193	78.345	79.497
7	80.649	81.801	82.953	84.105	85.257	86.410	87.562	88.714	89.866	91.018
8	92.170	93.322	94.474	95.627	96.779	97.931	99.083	100.235	101.387	102.539
9	103.691	104.844	105.996	107.148	108.300	109.452	110.604	111.756	112.908	114.061

KILOGRAM-CENTIMETERS TO INCH-POUNDS—1 kg-cm = 0.86796 in.-lb.

kg-cm	Units									
Tens	0	1	2	3	4	5	6	7	8	9
0	....	0.8680	1.7359	2.6039	3.4718	4.3398	5.2078	6.0757	6.9437	7.8116
1	8.6796	9.5476	10.4155	11.2835	12.1514	13.0194	13.8874	14.7553	15.6233	16.4912
2	17.3592	18.2272	19.0951	19.9631	20.8310	21.6990	22.5670	23.4349	24.3029	25.1708
3	26.0388	26.9068	27.7747	28.6427	29.5106	30.3786	31.2466	32.1145	32.9825	33.8504
4	34.7184	35.5864	36.4543	37.3223	38.1902	39.0582	39.9262	40.7941	41.6621	42.5300
5	43.3980	44.2660	45.1339	46.0019	46.8698	47.7378	48.6058	49.4737	50.3417	51.2096
6	52.0776	52.9456	53.8135	54.6815	55.5494	56.4174	57.2854	58.1533	59.0213	59.8892
7	60.7572	61.6252	62.4931	63.3611	64.2290	65.0970	65.9650	66.8329	67.7009	68.5688
8	69.4368	70.3048	71.1727	72.0407	72.9086	73.7766	74.6446	75.5125	76.3805	77.2484
9	78.1164	78.9844	79.8523	80.7203	81.5882	82.4562	83.3242	84.1921	85.0601	85.9280

PROPERTIES OF TUBULAR AND SOLID BEAMS

Any member of a structure whose principal function is to resist bending actions is known as a beam. The following is an elementary discussion of the various factors influencing the design of beams. In this discussion beams are assumed to be of uniform cross section throughout, the fibre stress to be within the elastic limit of the material and the loads and reactions to lie in a vertical plane perpendicular to the axis of the beam before loading.

Beams fall under four main classifications:

1. Cantilever Beams having one end fixed and the other end unsupported (figure 1).

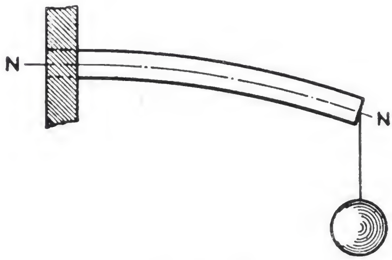


Figure 1

2. Simple Beams resting on two supports (figure 2).

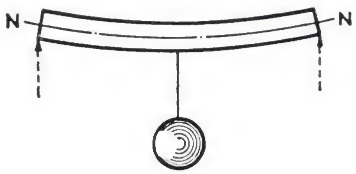


Figure 2

3. Fixed Beams having one or both ends fixed (figure 3).

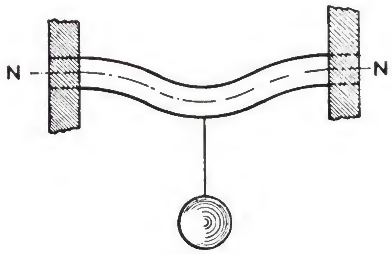


Figure 3

Fixed beams are stronger than simply supported beams of the same size and material because of the additional restraining forces at the fixed ends. Calculation of these restraining conditions may be made by replacing the condition of restraint by an imaginary span of length zero at the fixed ends.

4. Continuous Beams resting on three or more supports (figure 4).

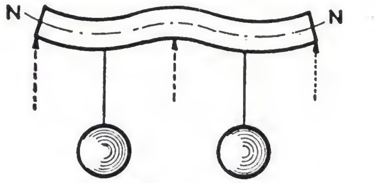


Figure 4

The principal stresses in simple beams are tension and compression. The fibres above the neutral surface (figure 2, N-N) are under compressional stresses, thereby shortened, while those below are under tensional stresses and consequently lengthened. The fibres along the neutral surface plane N-N are not stressed. The stress on any fibre of a beam is directly proportional to the distance of the fibre from the neutral surface. See figure 5.

Neutral Surface: The plane N-N at which the fibres are not stressed. This neutral surface always passes through the center of gravity of the cross section.

Neutral Axis: The line of intersection of the neutral surface and a cross sectional plane. See figure 5.

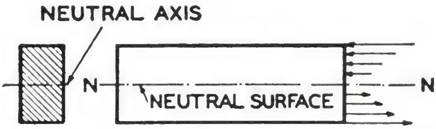


Figure 5

Elastic Curve: The curve formed by the line N-N, or neutral surface of a beam as it deflects under its own weight and the weight of loads upon it.

Maximum Deflection: The greatest distance from the neutral surface (of the unstressed beam) to the elastic curve (neutral surface) of the loaded beam. The maximum deflection occurs at the place where the slope is zero on the beam. (See pages D111-125).

Reactions at Supports: The upward pressures at the supports which prevent the beam from moving downwards are the reactions at supports. It is a fundamental principle of mechanics that the sum of the loads must equal the sum of the reactions. In the case of simple and cantilever beams, the reactions are determined by applying conditions of static equilibrium in which for a system of vertical forces in the same plane the algebraic sum of all the forces must equal zero. The reactions are determined from the equation of the elastic curve in the case of fixed beams. For continuous beams the theorem of three moments may be used.

Shearing Stresses: A beam when loaded is subjected to transverse stresses which tend to shear the beam as illustrated at section X-X (figure 6).

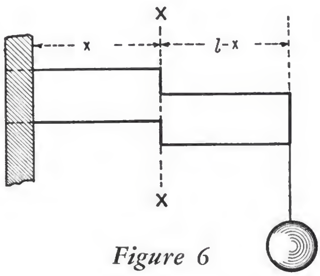


Figure 6

At any cross section, such as X-X, the vertical shear is equal to the algebraic sum of all the forces on either side of the section. If forces are taken to the left of the section, the vertical shear equals the reaction at the left support minus the sum of the loads (including the weight of the beam) between the left support and the section considered. Forces which act upward are considered positive and downward forces negative when acting to the left of the section considered. The signs are reversed for forces to the right of the section. Generally the shearing stresses for steel beams are much smaller than those of tension and compression and may be ignored. However, if the loads are near the support and the beam is short the shearing stress may be greater than the bending stresses. Shearing stress is considered to be uniform over the cross section.

Bending Moment: The tendency of the external forces acting on a beam to produce rotation about any chosen cross section is called the bending moment. This tendency, or bending moment, is the product of the force P acting on the beam multiplied by the lever arm l, or Pl, at section Y-Y (figure 7).

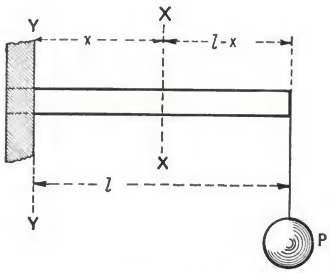


Figure 7

Similarly at section X-X, the bending moment is $P(l—x)$. Bending moment is usually expressed in inch-pounds, the force P being in pounds and the lever arms in inches. Where the lever arm is in feet the bending moment is in foot-pounds. Bending moments to the left of the section considered and which tend to produce clockwise rotation are positive; those which tend to produce counterclockwise rotation are negative. Bending moments to the right of the section considered are reversed from those to the left. The algebraic sum of the moments $= 0$. Thus in figure 8, moments about the right support $R_2 = 0$ or

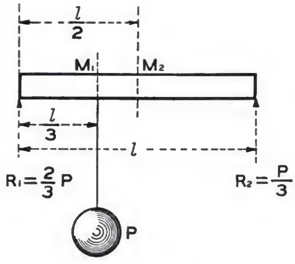


Figure 8

$$M_2 = R_1 l - \frac{2\,Pl}{3} = 0 \quad \text{from which} \quad R_1 = \frac{2\,P}{3}$$

Similarly, moments about the left support $R_1 = 0$, and the moment equation becomes

$$P\,\frac{l}{3} - R_2 l = 0 \quad \text{from which} \quad R_2 = \frac{P}{3}$$

The bending moment at the section M_1 is then $\frac{R_1 l}{3}$ or $\frac{2}{9}Pl$ and at M_2 considering forces to the left the moment is $\frac{2}{3}\,P\left(\frac{l}{2}\right) - P\left(\frac{l}{2} - \frac{l}{3}\right) = \frac{Pl}{6}$

To the right of M_2 the moment is $\left(-\frac{P}{3}\right)\left(\frac{l}{2}\right) = -\frac{Pl}{6}$

Beams must be designed for the maximum shearing stresses and bending moments.

Resisting Moment: The external forces acting on a beam create horizontal internal forces which resist the action of the external forces (see figure 9).

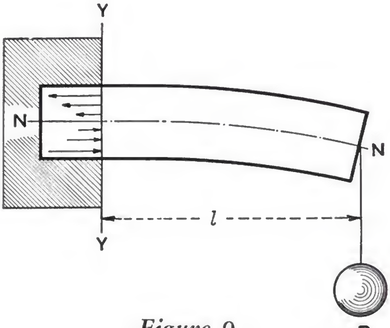


Figure 9

Thus the tendency of the beam to rotate about section Y-Y is resisted by the internal tensile forces above the neutral surface N-N and the internal compressive forces below. Thus it is evident that the sum of moments of each of the internal resisting forces must equal the bending moment Pl. The moments

for the individual internal forces are equal to the product of the internal force multiplied by its distance from the neutral surface N-N. Then the resisting moment for steel not stressed beyond the elastic limit is

$$M_R = fS = f\frac{I}{c} \text{ where}$$

M_R = Resisting moment in inch-pounds
f = Stress, pounds per square inch, in fibre farthest from neutral surface, N-N.
I = Moment of inertia of cross section.
c = Distance from neutral surface, N-N, to extreme fibre.
S = Section modulus $= \frac{I}{c}$

Moment of Inertia: I. This is the property of the cross section which determines the stiffness of the beam or its ability to resist deflection. It is the sum of the products of each of the elementary areas "a" multiplied by the square of their distance "b" from the neutral axis, figure 10.

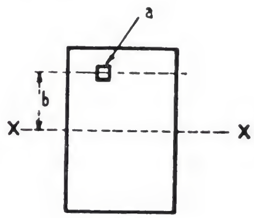


Figure 10

Other things being equal the stiffness of a beam is proportional to its moment of inertia of cross section.

Section Modulus: S. This is the property of the cross section which determines the strength of the beam. The section modulus is found by dividing the Moment of Inertia by the distance from the neutral surface to the extreme fibre, or $S = \frac{I}{c}$.

The two properties, Moment of Inertia and Section Modulus, are of the greatest importance in designing beams.

Strength of Beams: The maximum load a beam can safely support is one which develops the maximum safe working stress in the extreme or most strained fibre. The suitable cross section can be determined by satisfying the equation.

$$M = M_R = fS = f\frac{I}{c}$$

where M = maximum bending moment.

The transverse shear due to external forces must be resisted by internal transverse stresses at the section, or $S = f_s A$

in which S = shearing force in pounds
f_s = safe shearing stress in pounds per square inch
A = area of cross section in inches.

For formulas applying to various conditions of loading and supporting beams, see pages D111-125. The properties of beam cross sections are shown on pages D166-172.

LIST OF SYMBOLS

A	Area of cross section in square inches
B	Bending factor (A/S)
b	Breadth or width
c	Distance from neutral axis to extreme fibre
D	Outer diameter in inches
d	Inner diameter in inches, or overall depth
Δ	Deflection of beam in inches
σ	Unit deformation or strain
E	Modulus of elasticity $\left(\frac{f}{\sigma}\right)$ in pounds per square inch
f	Unit stress in pounds per square inch
G	Modulus of shear
I	Moment of inertia
L	Length in feet
l	Length in inches
M	Moment of force including bending moment
P	Force or concentrated load
R	Reaction, or outer radius of shaft
r	Radius of gyration or inner radius of shaft
S	Section modulus $\left(\frac{I}{c}\right)$
t	Thickness, temperature
V	Total shear
v	Unit shear
W	Total load
w	Load per unit length
x	Distance measured along X axis
y	Distance measured along Y axis
θ	Angle of twist per unit length
θl	Total angle of twist

Deviations from these symbols are indicated at the places of exception.

MECHANICS OF MATERIALS
FREQUENTLY USED FORMULAS

The formulas given below are frequently required in structural designing. They are included herein for the convenience of those engineers who have infrequent use for such formulas and hence may find reference necessary.

BEAMS

Flexural stress at extreme fiber:

$f = Mc/I = M/S$

Flexural stress at any fiber:

$f = My/I$ $\quad$ y = distance from neutral axis to fiber.

Average vertical shear (for maximum see below):

$v = V/A = V/dt$ (for beams and girders)

Horizontal shearing stress at any section A-A:

$v = VQ/Ib$ $\quad$ Q = statical moment about the neutral axis of that portion of the cross-section lying outside of section A-A,
b = width at section A-A

(Intensity of vertical shear is equal to that of horizontal shear acting normal to it at the same point and both are usually a maximum at mid-height of beam.)

Slope and deflection at any point:

$EI\dfrac{d^2y}{dx^2} = M$ $\quad$ x and y are abscissa and ordinate respectively of a point on the neutral axis, referred to axes of rectangular coordinates through a selected point of support.

(First integration gives slopes; second integration gives deflections. Constants of integration must be determined.)

CONTINUOUS BEAMS

Uniform load: $M_a\dfrac{l_1}{I_1} + 2M_b\left(\dfrac{l_1}{I_1}+\dfrac{l_2}{I_2}\right) + M_c\dfrac{l_2}{I_2} = -\dfrac{1}{4}\left(\dfrac{w_1 l_1^3}{I_1}+\dfrac{w_2 l_2^3}{I_2}\right)$

Concentrated loads:

$$M_a\frac{l_1}{I_1} + 2M_b\left(\frac{l_1}{I_1}+\frac{l_2}{I_2}\right) + M_c\frac{l_2}{I_2} = -\frac{P_1 a_1 b_1}{I_1}\left(1+\frac{a_1}{l_1}\right) - \frac{P_2 a_2 b_2}{I_2}\left(1+\frac{b_2}{l_2}\right)$$

Considering any two consecutive spans in any continuous structure:

M_a, M_b, M_c = moments at left, center, and right supports respectively.
l_1 and l_2 = length of left and right spans respectively.
I_1 and I_2 = moment of inertia of left and right spans respectively.
w_1 and w_2 = load per unit of length on left and right spans respectively.
P_1 and P_2 = concentrated loads on left and right spans respectively.
a_1 and a_2 = distance of concentrated loads from left support in left and right spans respectively.
b_1 and b_2 = distance of concentrated loads from right support in left and right spans respectively.

The above equations are for beams with variable moment of inertia continuous over three or more supports. By writing such an equation for each successive pair of spans and introducing the known values of end moments, all other moments can be found.

COLUMNS

Concentrically loaded:

$f = P/A$

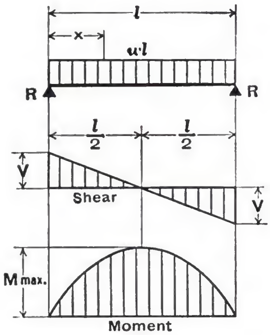
Eccentrically loaded:

$f = P/A + Mc/I.$ Bending in plane of principal axis. Deflection not considered.

$= \dfrac{P}{A}(1 + ec/r^2)$ $\quad$ e = eccentricity of load.

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD



Equivalent Tabular Load . . . $= wl$

$R = V$ . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

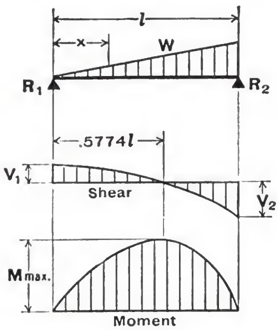
$M_{max.}$ (at center) . . . . . $= \frac{wl^2}{8}$

M_x . . . . $= \frac{wx}{2}(l - x)$

Δ_{max} (at center) . . . . . $= \frac{5\,wl^4}{384\,EI}$

Δ_x . . . . $= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

2. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO ONE END



Equivalent Tabular Load . . . $= \frac{16W}{9\sqrt{3}} = 1.0264W$

$R_1 = V_1$ . . . . $= \frac{W}{3}$

$R_2 = V_2$ max. . . . . $= \frac{2W}{3}$

V_x . . . . $= \frac{W}{3} - \frac{Wx^2}{l^2}$

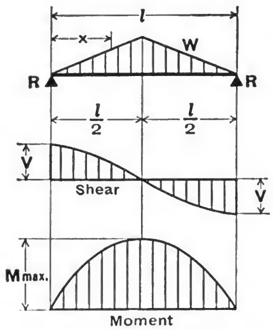
$M_{max.}$ $\left(\text{at } x = \frac{l}{\sqrt{3}} = .5774\,l\right)$. . . $= \frac{2Wl}{9\sqrt{3}} = .1283\,Wl$

M_x . . . . $= \frac{Wx}{3l^2}(l^2 - x^2)$

$\Delta_{max.}$ $\left(\text{at } x = l\sqrt{1 - \sqrt{\frac{8}{15}}} = .5193\,l\right) = .01304\,\frac{Wl^3}{EI}$

Δ_x . . . . $= \frac{Wx}{180EI\,l^2}(3x^4 - 10\,l^2x^2 + 7\,l^4)$

3. SIMPLE BEAM—LOAD INCREASING UNIFORMLY TO CENTER



Equivalent Tabular Load . . . $= \frac{4W}{3}$

$R = V$ . . . . $= \frac{W}{2}$

V_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= \frac{W}{2l^2}(l^2 - 4x^2)$

$M_{max.}$ (at center) . . . . . $= \frac{Wl}{6}$

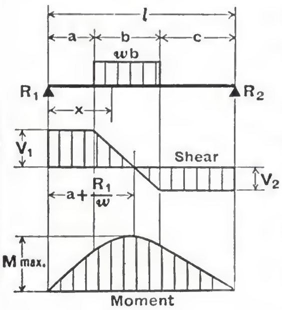
M_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . . $= Wx\left(\frac{1}{2} - \frac{2x^2}{3l^2}\right)$

$\Delta_{max.}$ (at center) . . . . $= \frac{Wl^3}{60EI}$

Δ_x . . . . $= \frac{Wx}{480EI\,l^2}(5l^2 - 4x^2)^2$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

4. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED



$R_1 = V_1 \left(\text{max. when } a < c\right) \ldots = \dfrac{wb}{2l}(2c+b)$

$R_2 = V_2 \left(\text{max. when } a > c\right) \ldots = \dfrac{wb}{2l}(2a+b)$

$V_x \left(\text{when } x < a \text{ and } > (a+b)\right) \ldots = R_1 - w(x-a)$

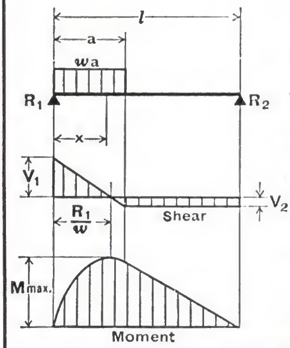
$M\text{max.} \left(\text{at } x = a + \dfrac{R_1}{w}\right) \ldots = R_1\left(a + \dfrac{R_1}{2w}\right)$

$M_x \left(\text{when } x < a\right) \ldots = R_1 x$

$M_x \left(\text{when } x > a \text{ and } < (a+b)\right) \ldots = R_1 x - \dfrac{w}{2}(x-a)^2$

$M_x \left(\text{when } x < (a+b)\right) \ldots = R_2 (l-x)$

5. SIMPLE BEAM—UNIFORM LOAD PARTIALLY DISTRIBUTED AT ONE END



$R_1 = V_1 \text{ max.} \ldots = \dfrac{wa}{2l}(2l-a)$

$R_2 = V_2 \ldots = \dfrac{wa^2}{2l}$

$V \left(\text{when } x < a\right) \ldots = R_1 - wx$

$M\text{max.} \left(\text{at } x = \dfrac{R_1}{w}\right) \ldots = \dfrac{R_1^2}{2w}$

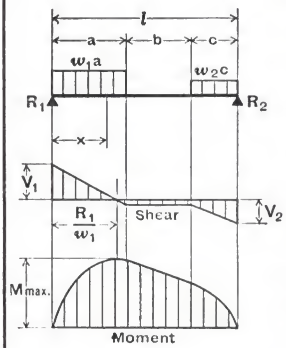
$M_x \left(\text{when } x < a\right) \ldots = R_1 x - \dfrac{wx^2}{2}$

$M_x \left(\text{when } x > a\right) \ldots = R_2 (l-x)$

$\Delta x \left(\text{when } x < a\right) \ldots = \dfrac{wx}{24EIl}\left(a^2(2l-a)^2 - 2ax^2(2l-a) + lx^3\right)$

$\Delta x \left(\text{when } x > a\right) \ldots = \dfrac{wa^2(l-x)}{24EIl}(4xl - 2x^2 - a^2)$

6. SIMPLE BEAM—UNIFORM LOADS PARTIALLY DISTRIBUTED AT EACH END



$R_1 = V_1 \ldots = \dfrac{w_1 a(2l-a) + w_2 c^2}{2l}$

$R_2 = V_2 \ldots = \dfrac{w_2 c(2l-c) + w_1 a^2}{2l}$

$V_x \left(\text{when } x < a\right) \ldots = R_1 - w_1 x$

$V_x \left(\text{when } x > a \text{ and } < (a+b)\right) \ldots = R_1 - R_2$

$V_x \left(\text{when } x > (a+b)\right) \ldots = R_2 - w_2(l-x)$

$M\text{max.} \left(\text{at } x = \dfrac{R_1}{w_1} \text{ when } R_1 < w_1 a\right) \ldots = \dfrac{R_1^2}{2w_1}$

$M\text{max.} \left(\text{at } x = l - \dfrac{R_2}{w_2} \text{ when } R_2 < w_2 c\right) = \dfrac{R_2^2}{2w_2}$

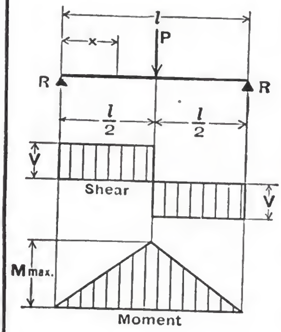
$M_x \left(\text{when } x < a\right) \ldots = R_1 x - \dfrac{w_1 x^2}{2}$

$M_x \left(\text{when } x > a \text{ and } < (a+b)\right) \ldots = R_1 x - \dfrac{w_1 a}{2}(2x - a)$

$M_x \left(\text{when } x > (a+b)\right) \ldots = R_2 (l-x) - \dfrac{w_2 (l-x)^2}{2}$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

7. SIMPLE BEAM—CONCENTRATED LOAD AT CENTER



Equivalent Tabular Load . . . . . . $= 2P$

R = V . . . . $= \frac{P}{2}$

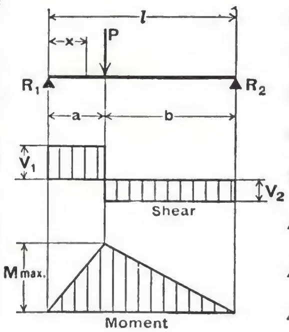
M max. (at point of load) . . . . $= \frac{Pl}{4}$

M_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= \frac{Px}{2}$

Δmax. (at point of load) . . . . $= \frac{Pl^3}{48EI}$

Δ_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . $= \frac{Px}{48EI}(3l^2 - 4x^2)$

8. SIMPLE BEAM—CONCENTRATED LOAD AT ANY POINT



Equivalent Tubular Load . . . . . . $= \frac{8\,Pab}{l^2}$

$R_1 = V_1$ (max. when $a < b$) . . . . . . $= \frac{Pb}{l}$

$R_2 = V_2$ (max. when $a > b$) . . . . . . $= \frac{Pa}{l}$

M max. (at point of load) . . . . . . $= \frac{Pab}{l}$

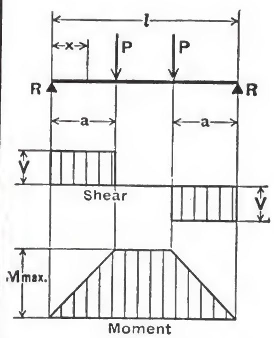
M_x (when $x < a$) . . . . . . $= \frac{Pbx}{l}$

Δmax. $\left(\text{at } x = \sqrt{\frac{a\,(a+2b)}{3}} \text{ when } a > b\right)$ $= \frac{Pab\,(a+2b)\sqrt{3a\,(a+2b)}}{27\,EI\,l}$

Δa (at point of load) . . . . . . $= \frac{Pa^2b^2}{3EI\,l}$

Δ_x (when $x < a$) . . . . . . $= \frac{Pbx}{6EI\,l}(l^2 - b^2 - x^2)$

9. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS SYMMETRICALLY PLACED



Equivalent Tabular Load . . . . $= \frac{8\,Pa}{l}$

R = V . . . . $= P$

M max. (between loads) . . . . $= Pa$

M_x (when $x < a$) . . . . $= Px$

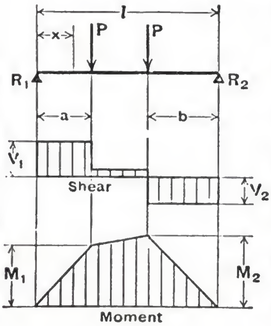
Δmax. (at center) . . . . $= \frac{Pa}{24EI}(3l^2 - 4a^2)$

Δ_x (when $x < a$) . . . . $= \frac{Px}{6EI}(3la - 3a^2 - x^2)$

Δ_x (when $x > a$ and $< (l - a)$) . . $= \frac{Pa}{6EI}(3lx - 3x^2 - a^2)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

10. SIMPLE BEAM—TWO EQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



$R_1 = V_1 \left(\text{max. when } a < b\right)$ . . . . . $= \frac{P}{l}(l - a + b)$

$R_2 = V_2 \left(\text{max. when } a > b\right)$ . . . . . $= \frac{P}{l}(l - b + a)$

$V_x \quad \left(\text{when } x > a \text{ and } < (l - b)\right)$ . . $= \frac{P}{l}(b - a)$

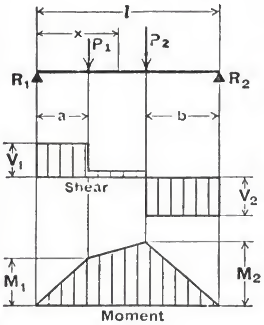
$M_1 \quad \left(\text{max. when } a > b\right)$ . . . . . $= R_1 a$

$M_2 \quad \left(\text{max. when } a < b\right)$ . . . . . $= R_2 b$

$M_x \quad \left(\text{when } x < a\right)$ . . . . $= R_1 x$

$M_x \quad \left(\text{when } x > a \text{ and } < (l - b)\right)$ . . $= R_1 x - P(x - a)$

11. SIMPLE BEAM—TWO UNEQUAL CONCENTRATED LOADS UNSYMMETRICALLY PLACED



$R_1 = V_1$ . . . . $= \frac{P_1(l - a) + P_2 b}{l}$

$R_2 = V_2$ . . . . $= \frac{P_1 a + P_2(l - b)}{l}$

$V_x \quad \left(\text{when } x > a \text{ and } < (l - b)\right)$ . . $= R_1 - P_1$

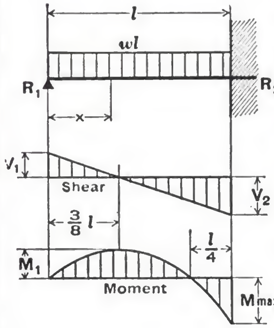
$M_1 \quad \left(\text{max. when } R_1 < P_1\right)$ . . . . $= R_1 a$

$M_2 \quad \left(\text{max. when } R_2 < P_2\right)$ . . . . $= R_2 b$

$M_x \quad \left(\text{when } x < a\right)$ . . . . $= R_1 x$

$M_x \quad \left(\text{when } x > a \text{ and } < (l - b)\right)$ . . $= R_1 x - P_1(x - a)$

12. BEAM FIXED AT ONE END, SUPPORTED AT OTHER—UNIFORMLY DISTRIBUTED LOAD



Equivalent Tabular Load . . . . . . $= wl$

$R_1 = V_1$ . . . . $= \frac{3wl}{8}$

$R_2 = V_2$ max. . . . . $= \frac{5wl}{8}$

V_x . . . . $= R_1 - wx$

M max. . . . . $= \frac{wl^2}{8}$

$M_1 \quad \left(\text{at } x = \frac{3}{8}l\right)$ . . . . $= \frac{9}{128}wl^2$

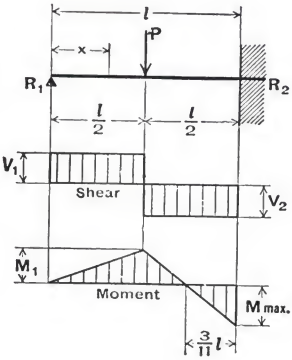
M_x . . . . $= R_1 x - \frac{wx^2}{2}$

$\Delta\text{max.} \quad \left(\text{at } x = \frac{l}{16}(1 + \sqrt{33}) = .4215l\right)$. $= \frac{wl^4}{185EI}$

Δ_x . . . . $= \frac{wx}{48EI}(l^3 - 3lx^2 + 2x^3)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

13. BEAM FIXED AT ONE END, SUPPORTED AT OTHER— CONCENTRATED LOAD AT CENTER



Equivalent Tabular Load . . . . . $= \frac{3P}{2}$

$R_1 = V_1$ . . . . $= \frac{5P}{16}$

$R_2 = V_2$ max. . . . . $= \frac{11P}{16}$

M max. (at fixed end). . . . . . . $= \frac{3Pl}{16}$

M_1 (at point of load) . . . . . $= \frac{5Pl}{32}$

M_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . . $= \frac{5Px}{16}$

M_x $\left(\text{when } x > \frac{l}{2}\right)$ . . . . . $= P\left(\frac{l}{2} - \frac{11x}{16}\right)$

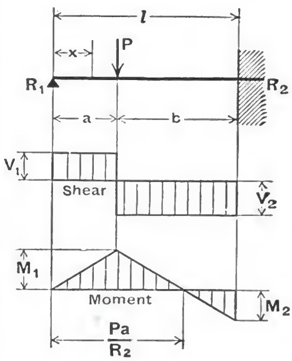
Δmax. $\left(\text{at } x = l\sqrt{\frac{1}{5}} = .4472l\right)$ . . $= \frac{Pl^3}{48EI\sqrt{5}} = .009317\,\frac{Pl^3}{EI}$

Δx (at point of load) . . . . $= \frac{7Pl^3}{768EI}$

Δx $\left(\text{when } x < \frac{l}{2}\right)$ . . . . . . $= \frac{Px}{96EI}\,(3l^2 - 5x^2)$

Δx $\left(\text{when } x > \frac{l}{2}\right)$ . . . . . . $= \frac{P}{96EI}\,(x - l)^2\,(11x - 2l)$

14. BEAM FIXED AT ONE END, SUPPORTED AT OTHER— CONCENTRATED LOAD AT ANY POINT



$R_1 = V_1$ . . . . $= \frac{Pb^2}{2l^3}\,(a + 2l)$

$R_2 = V_2$ . . . . $= \frac{Pa}{2l^3}\,(3l^2 - a^2)$

M_1 (at point of load) . . . . . $= R_1 a$

M_2 (at fixed end). . . . . . . $= \frac{Pab}{2l^2}\,(a + l)$

M_x (when $x < a$). . . . . . . $= R_1 x$

M_x (when $x > a$). . . . . . . $= R_1 x - P\,(x - a)$

Δmax. $\left(\text{when } a < .414l \text{ at } x = l\,\frac{l^2 + a^2}{3l^2 - a^2}\right)$ $= \frac{Pa}{3EI}\,\frac{(l^2 - a^2)^3}{(3l^2 - a^2)^2}$

Δmax. $\left(\text{when } a > .414l \text{ at } x = l\sqrt{\frac{a}{2l + a}}\right)$ $= \frac{Pab^2}{6EI}\sqrt{\frac{a}{2l + a}}$

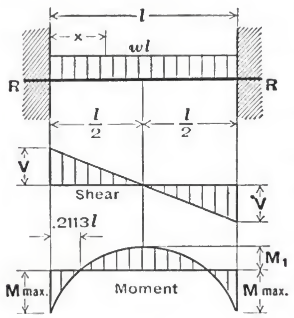
Δa (at point of load) . . . . $= \frac{Pa^2b^3}{12EIl^3}\,(3l + a)$

Δx (when $x < a$). . . . . . . $= \frac{Pb^2x}{12EIl^3}\,(3al^2 - 2lx^2 - ax^2)$

Δx (when $x > a$). . . . . . . $= \frac{Pa}{12EIl^3}\,(l - x)^2\,(3l^2x - a^2x - 2a^2l)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

15. BEAM FIXED AT BOTH ENDS—UNIFORMLY DISTRIBUTED LOADS



Equivalent Tabular Load . . . . . $= \frac{2wl}{3}$

R = V . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

M max. (at ends) . . . . $= \frac{wl^2}{12}$

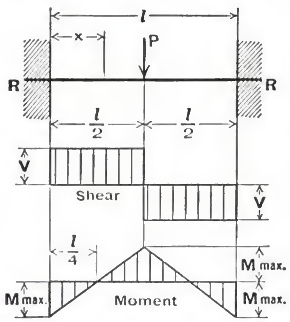
M_1 (at center) . . . . $= \frac{wl^2}{24}$

M_x . . . . $= \frac{w}{12}(6lx - l^2 - 6x^2)$

Δmax. (at center) . . . . $= \frac{wl^4}{384EI}$

Δx . . . . $= \frac{wx^2}{24EI}(l - x)^2$

16. BEAM FIXED AT BOTH ENDS—CONCENTRATED LOAD AT CENTER



Equivalent Tabular Load . . . . . = P

R = V . . . . $= \frac{P}{2}$

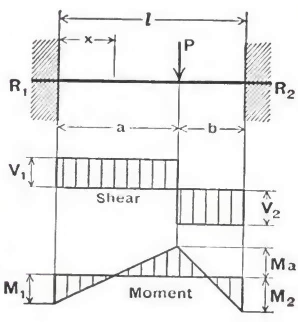
M max. (at center and ends) . . . . $= \frac{Pl}{8}$

M_x $\left(\text{when } x < \frac{l}{2}\right)$ . . . . . . $= \frac{P}{8}(4x - l)$

Δmax. (at center) . . . . $= \frac{Pl^3}{192EI}$

Δx . . . . $= \frac{Px^2}{48EI}(3l - 4x)$

17. BEAM FIXED AT BOTH ENDS—CONCENTRATED LOAD AT ANY POINT



$R_1 = V_1$ (max. when a < b) . . . . $= \frac{Pb^2}{l^3}(3a + b)$

$R_2 = V_2$ (max. when a > b) . . . . $= \frac{Pa^2}{l^3}(a + 3b)$

M_1 (max. when a < b) . . . . $= \frac{Pab^2}{l^2}$

M_2 (max. when a > b) . . . . $= \frac{Pa^2b}{l^2}$

Ma (at point of load) . . . . $= \frac{2Pa^2b^2}{l^3}$

M_x (when x < a) . . . . $= R_1x - \frac{Pab^2}{l^2}$

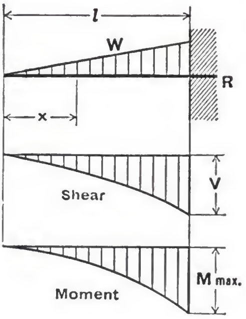
Δmax. $\left(\text{when } a > b \text{ at } x = \frac{2al}{3a + b}\right)$ . . $= \frac{2Pa^3b^2}{3EI(3a + b)^2}$

Δa (at point of load) . . . . $= \frac{Pa^3b^3}{3EIl^3}$

Δx (when x < a) . . . . $= \frac{Pb^2x^2}{6EIl^3}(3al - 3ax - bx)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

18. CANTILEVER BEAM—LOAD INCREASING UNIFORMLY TO FIXED END



Equivalent Tabular Load . . . . $= \frac{8}{3} W$

R = V . . . . $= W$

V_x . . . . $= W \frac{x^2}{l^2}$

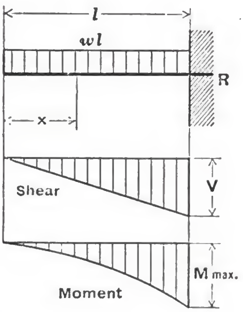
M max. (at fixed end) . . . . $= \frac{Wl}{3}$

M_x . . . . $= \frac{Wx^3}{3l^2}$

Δmax. (at free end) . . . . $= \frac{Wl^3}{15EI}$

Δ_x . . . . $= \frac{W}{60EIl^2}(x^5 - 5l^4x + 4l^5)$

19. CANTILEVER BEAM—UNIFORMLY DISTRIBUTED LOAD



Equivalent Tabular Load . . . . $= 4wl$

R = V . . . . $= wl$

V_x . . . . $= wx$

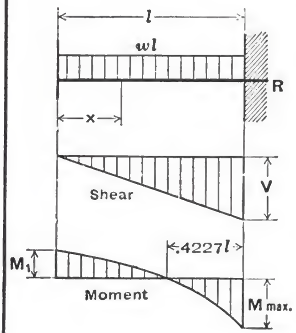
M max. (at fixed end) . . . . $= \frac{wl^2}{2}$

M_x . . . . $= \frac{wx^2}{2}$

Δmax. (at free end) . . . . $= \frac{wl^4}{8EI}$

Δ_x . . . . $= \frac{w}{24EI}(x^4 - 4l^3x + 3l^4)$

20. BEAM FIXED AT ONE END, FREE BUT GUIDED AT OTHER—UNIFORMLY DISTRIBUTED LOAD



The deflection at the guided end is assumed to be in a vertical plane.

Equivalent Tabular Load . . . . $= \frac{8}{3} wl$

R = V . . . . $= wl$

V_x . . . . $= wx$

M max. (at fixed end) . . . . $= \frac{wl^2}{3}$

M_1 (at guided end) . . . . $= \frac{wl^2}{6}$

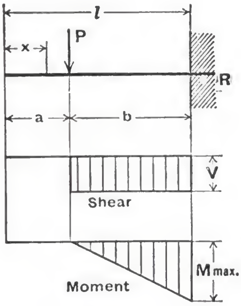
M_x . . . . $= \frac{w}{6}(l^2 - 3x^2)$

Δmax. (at guided end) . . . . $= \frac{wl^4}{24EI}$

Δ_x . . . . $= \frac{w(l^2 - x^2)^2}{24EI}$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

21. CANTILEVER BEAM—CONCENTRATED LOAD AT ANY POINT



Equivalent Tabular Load . . . . . $= \frac{8Pb}{l}$

$R = V$ (when $x < a$) . . . . $= P$

M max. (at fixed end) . . . . $= Pb$

M_x (when $x > a$) . . . . $= P(x - a)$

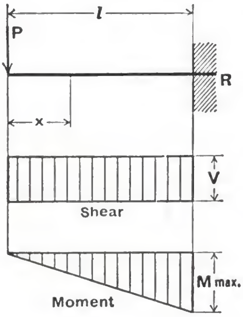
Δmax. (at free end) . . . . $= \frac{Pb^2}{6EI}(3l - b)$

Δa (at point of load) . . . . . $= \frac{Pb^3}{3EI}$

Δx (when $x < a$) . . . . $= \frac{Pb^2}{6EI}(3l - 3x - b)$

Δx (when $x > a$) . . . . $= \frac{P(l - x)^2}{6EI}(3b - l + x)$

22. CANTILEVER BEAM—CONCENTRATED LOAD AT FREE END



Equivalent Tabular Load . . . . . $= 8P$

$R = V$ . . . . $= P$

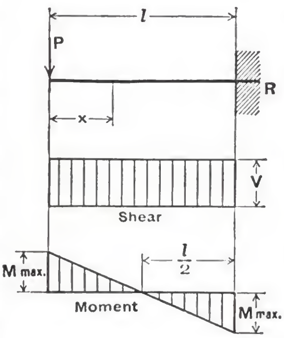
M max. (at fixed end) . . . . $= Pl$

M_x . . . . $= Px$

Δmax. (at free end) . . . . $= \frac{Pl^3}{3EI}$

Δx . . . . $= \frac{P}{6EI}(2l^3 - 3l^2x + x^3)$

23. BEAM FIXED AT ONE END, FREE BUT GUIDED AT OTHER—CONCENTRATED LOAD AT GUIDED END



The deflection at the guided end is assumed to be in a vertical plane.

Equivalent Tabular Load . . . . . $= 4P$

$R = V$ . . . . $= P$

M max. (at both ends) . . . . . . $= \frac{Pl}{2}$

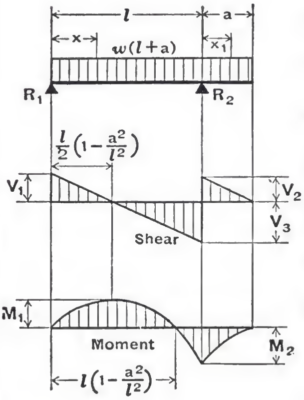
M_x . . . . $= P\left(\frac{l}{2} - x\right)$

Δmax. (at guided end) . . . . . . $= \frac{Pl^3}{12EI}$

Δx . . . . $= \frac{P(l - x)^2}{12EI}(l + 2x)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

24. BEAM OVERHANGING ONE SUPPORT—UNIFORMLY DISTRIBUTED LOAD



$R_1 = V_1$ . . . . $= \frac{w}{2l}(l^2 - a^2)$

$R_2 = V_2 + V_3$ . . . . $= \frac{w}{2l}(l+a)^2$

V_2 . . . . $= wa$

V_3 . . . . $= \frac{w}{2l}(l^2 + a^2)$

V_x (between supports) . . . $= R_1 - wx$

V_{x_1} (for overhang) . . . . $= w(a - x_1)$

M_1 $\left(\text{at } x = \frac{l}{2}\left[1 - \frac{a^2}{l^2}\right]\right)$ . . $= \frac{w}{8l^2}(l+a)^2(l-a)^2$

M_2 (at R_2) . . . . $= \frac{wa^2}{2}$

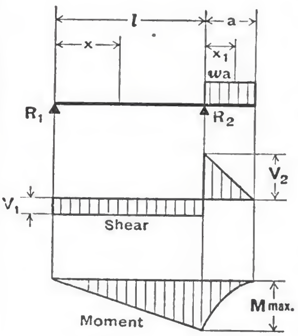
M_x (between supports) . . . $= \frac{wx}{2l}(l^2 - a^2 - xl)$

M_{x_1} (for overhang) . . . . $= \frac{w}{2}(a - x_1)^2$

Δx (between supports) . . . $= \frac{wx}{24EIl}(l^4 - 2l^2x^2 + lx^3 - 2a^2l^2 + 2a^2x^2)$

Δx_1 (for overhang) . . . . $= \frac{wx_1}{24EI}(4a^2l - l^3 + 6a^2x_1 - 4ax_1^2 + x_1^3)$

25. BEAM OVERHANGING ONE SUPPORT—UNIFORMLY DISTRIBUTED LOAD ON OVERHANG



$R_1 = V_1$ . . . . $= \frac{wa^2}{2l}$

$R_2 = V_1 + V_2$ . . . . $= \frac{wa}{2l}(2l + a)$

V_2 . . . . $= wa$

V_{x_1} (for overhang) . . . . $= w(a - x_1)$

M max. (at R_2) . . . . $= \frac{wa^2}{2}$

M_x (between supports) . . . $= \frac{wa^2x}{2l}$

M_{x_1} (for overhang) . . . . $= \frac{w}{2}(a - x_1)^2$

Δmax. $\left(\text{between supports at } x = \frac{l}{\sqrt{3}}\right) = \frac{wa^2l^2}{18\sqrt{3}\,EI} = .03208\,\frac{wa^2l^2}{EI}$

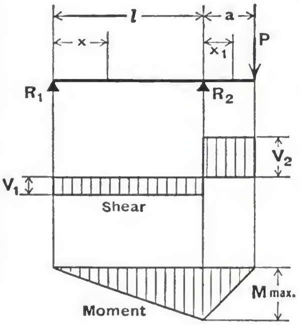
Δmax. (for overhang at $x_1 = a$) . $= \frac{wa^3}{24EI}(4l + 3a)$

Δx (between supports) . . . $= \frac{wa^2x}{12EIl}(l^2 - x^2)$

Δx_1 (for overhang) . . . . $= \frac{wx_1}{24EI}(4a^2l + 6a^2x_1 - 4ax_1^2 + x_1^3)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

26. BEAM OVERHANGING ONE SUPPORT—CONCENTRATED LOAD AT END OF OVERHANG



$R_1 = V_1$ . . . . $= \frac{Pa}{l}$

$R_2 = V_1 + V_2$ . . . . $= \frac{P}{l}(l + a)$

V_2 . . . . $= P$

$M\ max. \left(\text{at } R_2\right)$ . . . . $= Pa$

M_x $\left(\text{between supports}\right)$ . . . $= \frac{Pax}{l}$

M_{x_1} $\left(\text{for overhang}\right)$ . . . . $= P(a - x_1)$

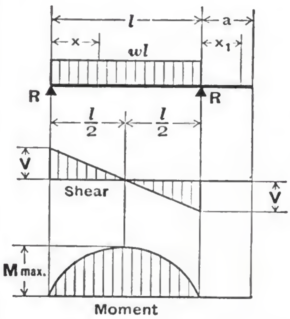
$\Delta max.$ $\left(\text{between supports at } x = \frac{l}{\sqrt{3}}\right)$ $= \frac{Pal^2}{9\sqrt{3}\,EI} = .06415\,\frac{Pal^2}{EI}$

$\Delta max.$ $\left(\text{for overhang at } x_1 = a\right)$. $= \frac{Pa^2}{3EI}(l + a)$

Δx $\left(\text{between supports}\right)$ . . . $= \frac{Pax}{6EIl}(l^2 - x^2)$

Δx_1 $\left(\text{for overhang}\right)$ . . . . $= \frac{Px_1}{6EI}(2al + 3ax_1 - x_1^2)$

27. BEAM OVERHANGING ONE SUPPORT—UNIFORMLY DISTRIBUTED LOAD BETWEEN SUPPORTS



Equivalent Tabular Load . . . . $= wl$

$R = V$ . . . . $= \frac{wl}{2}$

V_x . . . . $= w\left(\frac{l}{2} - x\right)$

$M\ max. \left(\text{at center}\right)$. . . . . . . $= \frac{wl^2}{8}$

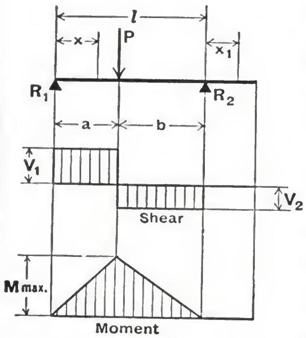
M_x . . . . $= \frac{wx}{2}(l - x)$

$\Delta max.$ $\left(\text{at center}\right)$. . . . . . . $= \frac{5wl^4}{384EI}$

Δx . . . . $= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

Δx_1 . . . . $= \frac{wl^3x_1}{24EI}$

28. BEAM OVERHANGING ONE SUPPORT—CONCENTRATED LOAD ANY POINT BETWEEN SUPPORTS



Equivalent Tabular Load . . . $= \frac{8Pab}{l^2}$

$R_1 = V_1 \left(\text{max. when } a < b\right)$ . . . $= \frac{Pb}{l}$

$R_2 = V_2 \left(\text{max. when } a > b\right)$ . . . $= \frac{Pa}{l}$

$M\ max. \left(\text{at point of load}\right)$ . . . $= \frac{Pab}{l}$

M_x $\left(\text{when } x < a\right)$ . . . . . $= \frac{Pbx}{l}$

$\Delta max.$ $\left(\text{at } x = \sqrt{\frac{a(a+2b)}{3}} \text{ when } a > b\right) = \frac{Pab\,(a + 2b)\,\sqrt{3a\,(a + 2b)}}{27EIl}$

Δa $\left(\text{at point of load}\right)$ . . . $= \frac{Pa^2b^2}{3EIl}$

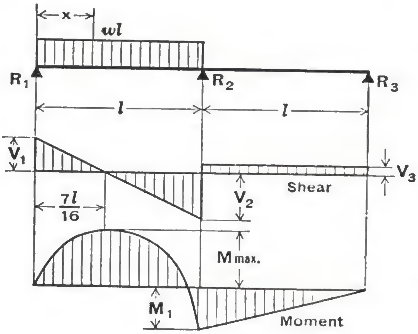
Δx $\left(\text{when } x < a\right)$ . . . . . $= \frac{Pbx}{6EIl}(l^2 - b^2 - x^2)$

Δx $\left(\text{when } x > a\right)$ . . . . . $= \frac{Pa\,(l - x)}{6EIl}(2lx - x^2 - a^2)$

Δx_1 . . . . $= \frac{Pabx_1}{6EIl}(l + a)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS STATIC LOADING CONDITIONS

29. CONTINUOUS BEAM—TWO EQUAL SPANS—UNIFORM LOAD ON ONE SPAN



Equivalent Tabular Load . = $\frac{49}{64}wl$

$R_1 = V_1$ . . . . = $\frac{7}{16}wl$

$R_2 = V_3 + V_3$ . . . . . . = $\frac{5}{8}wl$

$R_3 = V_3$ . . . . = $-\frac{1}{16}wl$

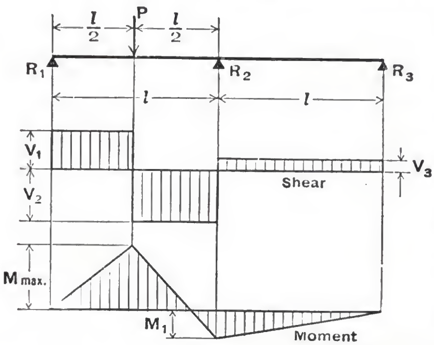
V_2 . . . . = $\frac{9}{16}wl$

M max. $\left(\text{at } x = \frac{7}{16}l\right)$ . . = $\frac{49}{512}wl^2$

M_1 (at support R_2) . = $\frac{1}{16}wl^2$

M_x (when $x < l$) . . = $\frac{wx}{16}(7l - 8x)$

30. CONTINUOUS BEAM—TWO EQUAL SPANS—CONCENTRATED LOAD AT CENTER OF ONE SPAN



Equivalent Tabular Load . = $\frac{13}{8}P$

$R_1 = V_1$ . . . . = $\frac{13}{32}P$

$R_2 = V_2 + V_3$ . . . . . . = $\frac{11}{16}P$

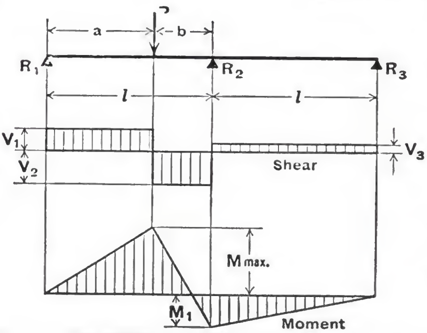
$R_3 = V_3$ . . . . = $-\frac{3}{32}P$

V_2 . . . . = $\frac{19}{32}P$

M max. (at point of load) . = $\frac{13}{64}Pl$

M_1 (at support R_2) . = $\frac{3}{32}Pl$

31. CONTINUOUS BEAM—TWO EQUAL SPANS—CONCENTRATED LOAD AT ANY POINT



$R_1 = V_1$ . . . . = $\frac{Pb}{4l^3}\left(4l^2 - a(l+a)\right)$

$R_2 = V_2 + V_3$ . . . . . . = $\frac{Pa}{2l^3}\left(2l^2 + b(l+a)\right)$

$R_3 = V_3$ . . . . = $-\frac{Pab}{4l^3}(l+a)$

V_2 . . . . = $\frac{Pa}{4l^3}\left(4l^2 + b(l+a)\right)$

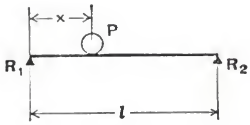
M max. (at point of load) . = $\frac{Pab}{4l^3}\left(4l^2 - a(l+a)\right)$

M_1 (at support R_2) . = $\frac{Pab}{4l^2}(l+a)$

BEAM DIAGRAMS AND FORMULAS
FOR VARIOUS CONCENTRATED MOVING LOADS

The values given in these formulas do not include impact which varies according to the requirements of each case.

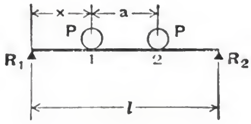
32. SIMPLE BEAM—ONE CONCENTRATED MOVING LOAD



$$R_1 \text{ max.} = V_1 \text{ max.} \left(\text{at } x = o\right) \quad . \ . \ . \ . \ . \quad = P$$

$$M \text{ max.} \left(\text{at point of load, when } x = \frac{l}{2}\right) \quad . \quad = \frac{Pl}{4}$$

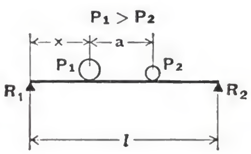
33. SIMPLE BEAM—TWO EQUAL CONCENTRATED MOVING LOADS



$$R_1 \text{ max.} = V_1 \text{ max.} \left(\text{at } x = o\right) \quad . \ . \ . \ . \ . \quad = \frac{2P}{l}\left(l - \frac{a}{2}\right)$$

$$M \text{ max.} \begin{cases} \left[\begin{array}{l}\text{when } a < (2 - \sqrt{2})\, l = .586l \\ \text{under load 1 at } x = \frac{1}{2}\left(l - \frac{a}{2}\right)\end{array}\right] & = \frac{P}{2l}\left(l - \frac{a}{2}\right)^2 \\ \left[\begin{array}{l}\text{when } a > (2 - \sqrt{2})\, l = .586l \\ \text{with one load at center of span} \\ \text{(case 32)}\end{array}\right] & = \frac{Pl}{4} \end{cases}$$

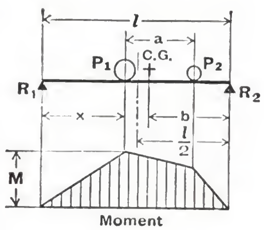
34. SIMPLE BEAM—TWO UNEQUAL CONCENTRATED MOVING LOADS



$$R_1 \text{ max.} = V_1 \text{ max.} \left(\text{at } x = o\right) \quad . \ . \ . \ . \ . \quad = P_1 + P_2 \frac{l - a}{l}$$

$$M \text{ max.} \begin{cases} \left[\text{under } P_1, \text{ at } x = \frac{1}{2}\left(l - \frac{P_2 a}{P_1 + P_2}\right)\right] & = \left(P_1 + P_2\right)\frac{x^2}{l} \\ \left[\begin{array}{l}\text{M max. may occur with larger} \\ \text{load at center of span and other} \\ \text{load off span (case 32)}\end{array}\right] & = \frac{P_1 l}{4} \end{cases}$$

GENERAL RULES FOR SIMPLE BEAMS CARRYING MOVING CONCENTRATED LOADS



The maximum shear due to moving concentrated loads occurs at one support when one of the loads is at that support. With several moving loads, the location that will produce maximum shear must be determined by trial.

The maximum bending moment produced by moving concentrated loads occurs under one of the loads when that load is as far from one support as the center of gravity of all the moving loads on the beam is from the other support.

In the accompanying diagram, the maximum bending moment occurs under load P_1 when $x = b$. It should also be noted that this condition occurs when the center line of the span is midway between the center of gravity of loads and the nearest concentrated load.

CONTINUOUS BEAM DIAGRAMS

EQUAL SPANS, SIMILARLY LOADED, CONSTANT MOMENT OF INERTIA
SUPPORTS AT SAME LEVEL

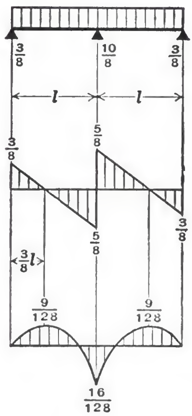
UNIFORMLY DISTRIBUTED LOAD

Reaction and shear coefficients of wl

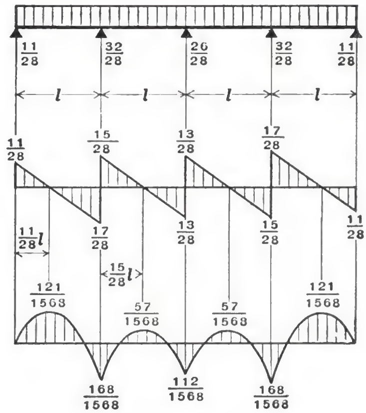
Moment coefficients of wl^2

w = Load per unit length

2 SPANS



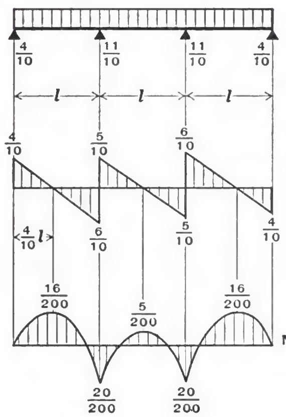
4 SPANS



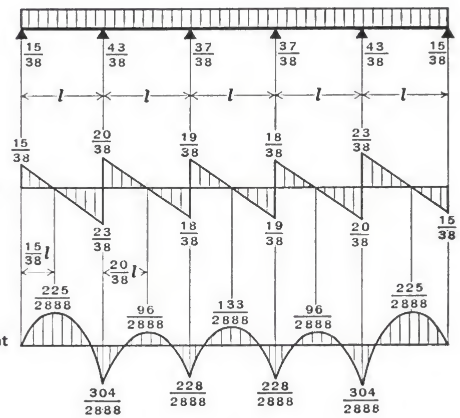
Shear

Moment

3 SPANS



5 SPANS



Shear

Moment

CONTINUOUS BEAM DIAGRAMS

EQUAL SPANS, SIMILARLY LOADED, CONSTANT MOMENT OF INERTIA
SUPPORTS AT SAME LEVEL

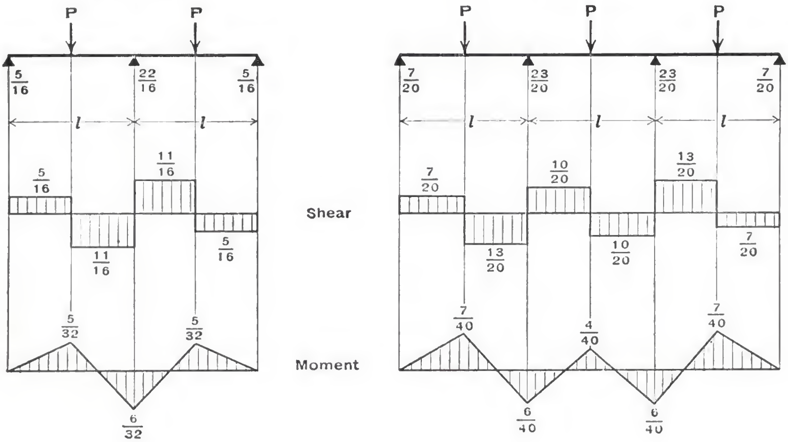
CONCENTRATED LOAD AT CENTERS

Reaction and shear coefficients of P

Moment coefficients of P*l*

2 SPANS

3 SPANS



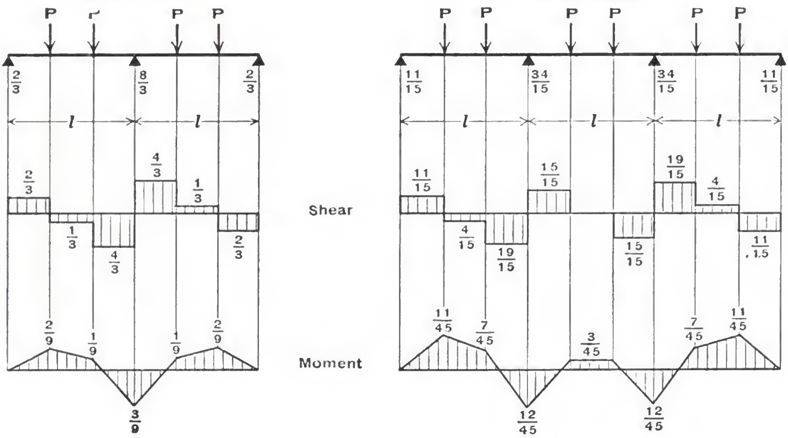
CONCENTRATED LOAD AT THIRD POINTS

Reaction and shear coefficients of P

Moment coefficients of P*l*

2 SPANS

3 SPANS



TORSION

When a material is subjected to torsion, the stresses introduced are shear, tension, and compression, all three stresses being of equal intensity.

In the case of cast iron, which has a high resistance to shear and a low resistance to tension, the failure will be a tension failure, with a fracture very near to a helicoid.

In other materials, with reverse characteristics, the failure will be a shear failure and the fracture a right section. If a force (P, figure 11) acts on a shaft fixed at one end it will produce torsional stresses in the shaft. The twisting moment equals Pr, which is the product of the twisting force and the distance of the force from the axis of the shaft. The twisting moment is usually expressed in inch-pounds, the distance in inches and the force in pounds. When the material is not stressed beyond its elastic limit:

A—The torsional moment at any cross section of a shaft under torsional stress is equal to the algebraic sum of the torsional moments acting between the section and the free end.

B—Each section of the shaft between the force P and the fixed end is rotated about the axis of the shaft.

C—The amount of rotation of any section will vary directly with the torsional force applied and with the distance of the section from the fixed end.

D—The amount of rotation of any point on a cross section will vary directly with its distance from the axis of the shaft.

From figure 11 it is seen that when the shaft is acted upon by the force P, the straight line *ab* becomes the helix *ac.* The angle *cxb* is called the angle of torsion, and the arc *cb* is the arc of torsion.

The amount of rotation of any point on a cross section of a shaft under torsional stress being proportional to its distance from the axis, and assuming the stresses to be within the elastic limit of the material, it follows that the stress in such a cross section varies directly from zero at the axis to a maximum at the fibre most distant from the axis.

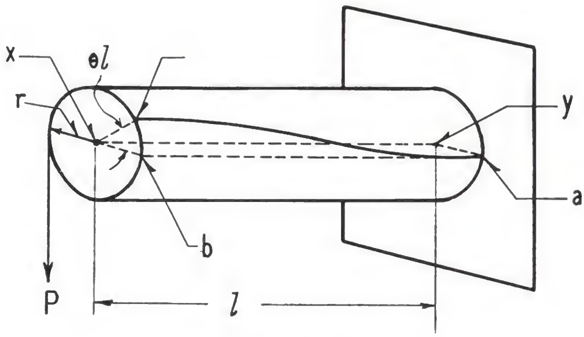


Figure 11

Torsional Formulas: For a condition of equilibrium (when the material is not stressed beyond its elastic limit) it may be proved for round shafts that:

$$M_t = M_r = f_s \frac{I_p}{c} \text{ or } f_s = \frac{M_t c}{I_p}$$

Also $\Theta = \dfrac{M_t}{GI_p}$ and $\Theta l = \dfrac{M_t l}{GI_p}$

where

M_t = Twisting moment in inch-pounds

M_r = Resisting moment in inch-pounds

f_s = Shearing stress at the extreme fibre in pounds per square inch

I_p = Polar moment of inertia. (For circular cross sections, the polar moment of inertia is twice the moment of inertia about a diameter)

c = Distance in inches of extreme fibre from neutral axis

$S_p = 2S = \frac{I_p}{c}$ = Polar section modulus for circular cross sections

G = Modulus of shear

From this it is seen that the unit stress in the surface fibre of a shaft under torsional stress is equal to the torsional moment divided by the polar section modulus of the section. Since torsional stress is not uniformly distributed over the cross sectional area, there can be no unit area over which the stress is uniform. Hence the unit stress S is the stress in a hypothetical area of one square inch, each element of which is subjected to the same stress as the surface fibre.

For circular cross sections the polar section modulus is equal to twice the section modulus, or:

$$S_p = 2S = 0.196 \frac{D^4 - d^4}{D}$$

where

D = Outside diameter of tube in inches

d = Inside diameter of tube in inches

In the case of a solid circular bar d = 0 and the formula becomes

$S_p = 0.196\ D^3$

For other than circular cross sections S_p does not equal the polar moment of inertia divided by the distance of the extreme fibre from the axis of rotation.

The torsional modulus of elasticity for steel is generally taken as 12,000,000.

Power Transmitted by Shafts: Assume that a circular shaft has a pulley at each end, both connected by belts, one to a machine and the other to an engine, and that neither belt slips—

and let

r = Radius in inches of the pulley connected to engine.

N = Number of revolutions of the pulley per minute.

P = Force in pounds applied to pulley by belt.

f = Stress in pounds per square inch in extreme fibre of shaft due to force P.

R = Radius of shaft in inches.

Then at each revolution of the pulley, the work performed by the force P is $2\pi rP$, and in N revolutions is $2\pi rNP$.

Therefore, horse-power $= \dfrac{2\pi rNP}{33000 \times 12}$

Twisting moment $= M_t = Pr = \dfrac{fI_p}{R}$

Hence horse-power $\dfrac{2\pi NfI_p}{33000 \times 12 \times R}$

For circular cross sections $I_p = \dfrac{\pi R^4}{2}$

Substituting, horse-power $= \dfrac{\pi^2 NfR^2}{96000}$

COLUMNS

A structural part that is subjected to compression and whose length is such that it will buckle or bend before it breaks is a *Column.* The length will depend upon the material in the column. The length of a column is the distance unsupported against lateral bending. Since the stresses in a loaded column are very complicated, no exact formula for them has ever been devised. The column formulas now used are the outcome of experiment and deduction.

The maximum stress on the surface fibre of a loaded column is composed of two stresses: (1) The unit stress due solely to compression.
(2) The unit stress due to the bending of the column.
The maximum fibre stress occurs in the fibre most distant from the neutral axis on the concaved side of the deflected column.

The condition of its ends has a relation to the strength of a column. The ends may be square (or flat), round, fixed, held by a pin, one end square and one rounded, etc. Columns with both ends square are strongest. Since most columns have square fixed ends, and since the formulas for fixed end columns have a large factor of safety, these are the formulas in general use except where they are obviously inapplicable.

Radius of Gyration: The strength of a column is measured by the radius of gyration of its cross section. Other things being equal, the column with the greater radius of gyration will be the stronger. The radius of gyration of a cross section is equal to the square root of the quotient of the moment of inertia divided by the area of the section.

$$r = \sqrt{\frac{I}{A}}$$

r = Radius of gyration of the cross section.
I = Moment of Inertia of the cross section.
A = Area of the cross section in square inches.

Ratio of Slenderness: This is the ratio between the unsupported length of the column and the least radius of gyration of the cross section. Both are expressed in inches.

$$\text{Ratio of Slenderness} = \frac{L}{r}$$

l = Unsupported length of column in inches.
r = Least radius of gyration in inches.

Building codes usually limit the unsupported length of a column to 120 times its least radius of gyration. In short the ratio of slenderness must not exceed 120 or the allowable unit stress is very much reduced.

Strength of Columns: The City of Chicago and the American Railway Engineering Association have adopted the following straight line formula for steel columns:

$f = 16000 - 70l/r$*

f = Allowable compressive stress for steel in pounds per square inch.
l = Unsupported length of column in inches.
r = Least radius of gyration in inches.

This formula applies to columns with flat ends having a ratio of slenderness not greater than 120 except when used as secondary members having a maximum allowable unit stress of 14,000 pounds per square inch and having the resultant of the compressive loads in line with the axis of the column.

Loaded columns which have a ratio of slenderness of approximately 20 or under, and which fail, will fail primarily because of direct compression. Columns with a slenderness ratio between 20 and 150 will fail by a combination of compression and bending stresses. Columns with a ratio of slenderness in excess of 150 will fail chiefly because of bending stresses.

Values for the radius of gyration of different sizes of tubing are given on pages D160-165. Above are formulas for the radius of gyration of various shapes of tubular and solid cross sections.

*A. I. S. C. formula may be used:
$$f = \frac{18000}{1 + \frac{1}{18000}\left(\frac{l^2}{r^2}\right)}$$

STANDARD PIPE COLUMNS

(Loads in tons of 2000 pounds, based on New York and Chicago Building Laws)

$$f = 16{,}000 - 70\frac{l}{r}$$

f = allowable compressive stress for steel, pounds per square inch;
l = length of column in inches; r = least radius of gyration in inches;
Maximum allowable compressive stress = 14,000 pounds per square inch.

Length, Feet	NOMINAL PIPE SIZE								
	2″	2½″	3″	3½″	4″	4½″	5″	6″	7″
	THICKNESS								
	.154	.203	.216	.226	.237	.247	.258	.280	.301
36	....	....	....	....	....	....	....	....	15.00
33	....	....	....	....	....	....	....	10.20	18.37
30	....	....	....	....	....	....	....	13.33	21.73
27	....	....	....	....	....	....	8.43	16.46	25.10
24	....	....	....	....	....	7.41	11.32	19.60	28.47
22	....	....	....	....	5.96	9.25	13.24	21.68	30.71
20	....	....	....	4.60	7.73	11.09	15.16	23.77	32.96
18	....	....	....	6.28	9.50	12.94	17.09	25.86	35.20
16	....	....	4.96	7.97	11.26	14.78	19.01	27.95	37.45
14	....	3.06	6.57	9.65	13.03	16.62	20.93	30.04	39.69
13	....	3.81	7.37	10.49	13.91	17.54	21.90	31.08	40.81
12	....	4.57	8.18	11.33	14.79	18.46	22.86	32.12	41.94
11	2.29	5.32	8.98	12.18	15.68	19.38	23.82	33.17	43.06
10	2.86	6.08	9.78	13.02	16.56	20.30	24.78	34.21	44.18
9	3.44	6.83	10.59	13.86	17.44	21.22	25.74	35.26	45.30
8	4.01	7.59	11.39	14.70	18.33	22.14	26.71	36.30	46.43
7	4.58	8.34	12.20	15.54	19.21	23.06	27.67	37.34	47.55
6	5.16	9.10	13.00	16.38	20.09	23.98	28.63	38.39	48.48
5	5.73	9.86	13.81	17.23	20.98	24.90	29.59	39.07	48.48

Length, Feet	NOMINAL PIPE SIZE						
	8″	9″	10″	11″	12″	13″	14″
	THICKNESS						
	.322	.342	.365	.375	.375	.375	.375
40	19.16	28.77	40.81	51.26	60.68	72.45	81.88
36	23.96	33.87	46.26	56.85	66.27	78.05	87.47
33	27.57	37.70	50.34	61.05	70.47	82.25	91.67
30	31.17	41.53	54.43	65.24	74.67	86.44	95.87
27	34.77	45.35	58.51	69.44	78.86	90.64	100.06
24	38.37	49.18	62.59	73.64	83.06	94.84	104.26
22	40.78	51.73	65.32	76.43	85.86	97.64	107.06
20	43.18	54.28	68.04	79.23	88.65	100.43	109.86
18	45.58	56.83	70.76	82.03	91.45	103.23	112.65
16	47.98	59.38	73.48	84.83	94.25	106.03	115.45
14	50.38	61.93	76.21	87.62	97.05	108.83	118.25
13	51.58	63.21	77.57	89.02	98.45	110.23	119.65
12	52.78	64.49	78.93	90.42	99.85	111.62	120.61
11	53.99	65.76	80.29	91.82	101.24	112.36	120.61
10	55.19	67.04	81.65	93.22	102.05	112.36	120.61
9	56.39	68.31	83.01	93.81	102.05	112.36	120.61
8	57.59	69.59	83.36	93.81	102.05	112.36	120.61
7	58.79	69.82	83.36	93.81	102.05	112.36	120.61
6	58.79	69.82	83.36	93.81	102.05	112.36	120.61
5	58.79	69.82	83.36	93.81	102.05	112.36	120.61

Loads above or to the left of the heavy line correspond to values of $\frac{l}{r}$ greater than 120.

EXTRA STRONG PIPE COLUMNS

(Loads in tons of 2000 pounds, based on New York and Chicago Building Laws)

$$f = 16{,}000 - 70\frac{l}{r}$$

f = allowable compressive stress for steel, pounds per square inch;
l = length of column in inches; r = least radius of gyration in inches;
Maximum allowable compressive stress = 14,000 pounds per square inch.

Length, Feet	2″	2½″	3″	3½″	4″	4½″	5″	6″	7″
Thickness	.218	.276	.300	.318	.337	.355	.375	.432	.500
36	....	....	....	....	....	....	....	....	22.52
33	....	....	....	....	....	....	....	14.16	28.11
30	....	....	....	....	....	....	....	18.99	33.69
27	....	....	....	....	....	....	11.21	23.81	39.28
24	....	....	....	....	....	9.74	15.39	28.64	44.86
22	....	....	....	....	7.68	12.38	18.19	31.86	48.58
20	....	....	....	5.78	10.19	15.02	20.98	35.07	52.31
18	....	....	....	8.14	12.69	17.66	23.77	38.29	56.03
16	....	....	6.29	10.51	15.20	20.31	26.56	41.51	59.75
14	....	3.69	8.52	12.87	17.71	22.95	29.35	44.72	63.48
13	....	4.71	9.64	14.06	18.96	24.27	30.75	46.33	65.34
12	....	5.74	10.75	15.24	20.22	25.59	32.15	47.94	67.20
11	2.91	6.76	11.87	16.42	21.47	26.91	33.54	49.55	69.06
10	3.72	7.79	12.98	17.60	22.72	28.23	34.94	51.16	70.92
9	4.53	8.81	14.09	18.79	23.98	29.55	36.33	52.76	72.78
8	5.34	9.83	15.21	19.97	25.23	30.88	37.73	54.37	74.64
7	6.15	10.86	16.32	21.15	26.48	32.20	39.12	55.98	76.51
6	6.96	11.88	17.44	22.33	27.74	33.52	40.52	57.59	78.34
5	7.77	12.91	18.55	23.52	28.99	34.84	41.92	58.83	78.34

Length, Feet	8″	9″	10″	11″	12″	13″	14″
Thickness	.500	.500	.500	.500	.500	.500	.500
40	27.60	40.14	54.25	66.80	79.36	95.06	107.62
36	35.05	47.59	61.71	74.26	86.82	102.52	115.08
33	40.64	53.18	67.30	79.85	92.41	108.11	120.67
30	46.23	58.77	72.89	85.45	98.00	113.70	126.27
27	51.81	64.36	78.48	91.04	103.60	119.30	131.86
24	57.40	69.95	84.07	96.63	109.19	124.89	137.45
22	61.13	73.68	87.80	100.36	112.92	128.62	141.18
20	64.85	77.40	91.53	104.09	116.65	132.35	144.91
18	68.58	81.13	95.26	107.82	120.38	136.08	148.64
16	72.30	84.86	98.98	111.54	124.11	139.81	152.37
14	76.03	88.58	102.71	115.27	127.84	143.54	156.10
13	77.89	90.45	104.58	117.14	129.70	145.40	157.97
12	79.75	92.31	106.44	119.00	131.56	147.27	159.44
11	81.61	94.17	108.30	120.87	133.43	148.44	159.44
10	83.48	96.04	110.17	122.73	134.70	148.44	159.44
9	85.34	97.90	112.03	123.70	134.70	148.44	159.44
8	87.20	99.76	112.70	123.70	134.70	148.44	159.44
7	89.06	100.33	112.70	123.70	134.70	148.44	159.44
6	89.34	100.33	112.70	123.70	134.70	148.44	159.44
5	89.34	100.33	112.70	123.70	134.70	148.44	159.44

Loads above or to the left of the heavy line correspond to values of $\frac{l}{r}$ greater than 120.

DOUBLE EXTRA STRONG PIPE COLUMNS

(Loads in tons of 2000 pounds, based on New York and Chicago Building Laws)

$$f = 16{,}000 - 70\frac{l}{r}$$

f = allowable compressive stress for steel, pounds per square inch;
l = length of column in inches; r = least radius of gyration in inches;
Maximum allowable compressive stress = 14,000 pounds per square inch.

Length, Feet	NOMINAL PIPE SIZE									
	2″	2½″	3″	3½″	4″	4½″	5″	6″	7″	8″
	THICKNESS									
	.436	.552	.600	.636	.674	.710	.750	.864	.875	.875
40	......	......	......	......	......	......	......	......	......	40.64
36	......	......	......	......	......	......	......	......	31.86	53.61
33	......	......	......	......	......	......	......	19.87	41.57	63.35
30	......	......	......	......	......	......	......	29.43	51.29	73.08
27	......	......	......	......	......	......	16.05	39.00	61.00	82.82
24	......	......	......	......	......	13.81	24.35	48.57	70.72	92.55
22	......	......	......	......	10.31	19.04	29.88	54.94	77.19	99.04
20	......	......	......	7.13	15.27	24.27	35.41	61.32	83.67	105.53
18	......	......	......	11.79	20.22	29.50	40.94	67.70	90.15	112.02
16	......	......	8.65	16.46	25.17	34.73	46.47	74.08	96.63	118.51
14	......	4.17	13.03	21.12	30.13	39.95	52.00	80.46	103.10	125.00
13	......	6.17	15.22	23.45	32.61	42.57	54.77	83.64	106.34	128.25
12	......	8.18	17.42	25.78	35.08	45.18	57.54	86.83	109.58	131.49
11	3.78	10.18	19.61	28.12	37.56	47.80	60.30	90.02	112.82	134.74
10	5.37	12.18	21.80	30.45	40.04	50.41	63.07	93.21	116.06	137.98
9	6.96	14.19	24.00	32.78	42.52	53.02	65.83	96.40	119.29	141.23
8	8.55	16.19	26.19	35.11	44.99	55.64	68.60	99.59	122.53	144.47
7	10.13	18.20	28.38	37.45	47.47	58.25	71.36	102.78	125.77	147.72
6	11.72	20.20	30.57	39.78	49.95	60.87	74.13	105.97	129.01	149.13
5	13.31	22.21	32.77	42.11	52.42	63.48	76.89	109.15	129.89	149.13

Loads above or to the left of the heavy line correspond to values of $\frac{l}{r}$ greater than 120.

DECIMAL EQUIVALENTS
FOR FRACTIONS OF AN INCH AND FOOT

Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions	Fractions of Inch or Foot		Inch Equivalents to Foot Fractions
	.0052	1/16		.2552	3 1/16		.5052	6 1/16		.7552	9 1/16
	.0104	1/8		.2604	3 1/8		.5104	6 1/8		.7604	9 1/8
1/64	.015625	3/16	17/64	.265625	3 3/16	33/64	.515625	6 3/16	49/64	.765625	9 3/16
	.0208	1/4		.2708	3 1/4		.5208	6 1/4		.7708	9 1/4
	.0260	5/16		.2760	3 5/16		.5260	6 5/16		.7760	9 5/16
1/32	.03125	3/8	9/32	.28125	3 3/8	17/32	.53125	6 3/8	25/32	.78125	9 3/8
	.0365	7/16		.2865	3 7/16		.5365	6 7/16		.7865	9 7/16
	.0417	1/2		.2917	3 1/2		.5417	6 1/2		.7917	9 1/2
3/64	.046875	9/16	19/64	.296875	3 9/16	35/64	.546875	6 9/16	51/64	.796875	9 9/16
	.0521	5/8		.3021	3 5/8		.5521	6 5/8		.8021	9 5/8
	.0573	11/16		.3073	3 11/16		.5573	6 11/16		.8073	9 11/16
1/16	.0625	3/4	5/16	.3125	3 3/4	9/16	.5625	6 3/4	13/16	.8125	9 3/4
	.0677	13/16		.3177	3 13/16		.5677	6 13/16		.8177	9 13/16
	.0729	7/8		.3229	3 7/8		.5729	6 7/8		.8229	9 7/8
5/64	.078125	15/16	21/64	.328125	3 15/16	37/64	.578125	6 15/16	53/64	.828125	9 15/16
	.0833	1		.3333	4		.5833	7		.8333	10
	.0885	1 1/16		.3385	4 1/16		.5885	7 1/16		.8385	10 1/16
3/32	.09375	1 1/8	11/32	.34375	4 1/8	19/32	.59375	7 1/8	27/32	.84375	10 1/8
	.0990	1 3/16		.3490	4 3/16		.5990	7 3/16		.8490	10 3/16
	.1042	1 1/4		.3542	4 1/4		.6042	7 1/4		.8542	10 1/4
7/64	.109375	1 5/16	23/64	.359375	4 5/16	39/64	.609375	7 5/16	55/64	.859375	10 5/16
	.1146	1 3/8		.3646	4 3/8		.6146	7 3/8		.8646	10 3/8
	.1198	1 7/16		.3698	4 7/16		.6198	7 7/16		.8698	10 7/16
1/8	.1250	1 1/2	3/8	.3750	4 1/2	5/8	.6250	7 1/2	7/8	.8750	10 1/2
	.1302	1 9/16		.3802	4 9/16		.6302	7 9/16		.8802	10 9/16
	.1354	1 5/8		.3854	4 5/8		.6354	7 5/8		.8854	10 5/8
9/64	.140625	1 11/16	25/64	.390625	4 11/16	41/64	.640625	7 11/16	57/64	.890625	10 11/16
	.1458	1 3/4		.3958	4 3/4		.6458	7 3/4		.8958	10 3/4
	.1510	1 13/16		.4010	4 13/16		.6510	7 13/16		.9010	10 13/16
5/32	.15625	1 7/8	13/32	.40625	4 7/8	21/32	.65625	7 7/8	29/32	.90625	10 7/8
	.1615	1 15/16		.4115	4 15/16		.6615	7 15/16		.9115	10 15/16
	.1667	2		.4167	5		.6667	8		.9167	11
11/64	.171875	2 1/16	27/64	.421875	5 1/16	43/64	.671875	8 1/16	59/64	.921875	11 1/16
	.1771	2 1/8		.4271	5 1/8		.6771	8 1/8		.9271	11 1/8
	.1823	2 3/16		.4323	5 3/16		.6823	8 3/16		.9323	11 3/16
3/16	.1875	2 1/4	7/16	.4375	5 1/4	11/16	.6875	8 1/4	15/16	.9375	11 1/4
	.1927	2 5/16		.4427	5 5/16		.6927	8 5/16		.9427	11 5/16
	.1979	2 3/8		.4479	5 3/8		.6979	8 3/8		.9479	11 3/8
13/64	.203125	2 7/16	29/64	.453125	5 7/16	45/64	.703125	8 7/16	61/64	.953125	11 7/16
	.2083	2 1/2		.4583	5 1/2		.7083	8 1/2		.9583	11 1/2
	.2135	2 9/16		.4635	5 9/16		.7135	8 9/16		.9635	11 9/16
7/32	.21875	2 5/8	15/32	.46875	5 5/8	23/32	.71875	8 5/8	31/32	.96875	11 5/8
	.2240	2 11/16		.4740	5 11/16		.7240	8 11/16		.9740	11 11/16
	.2292	2 3/4		.4792	5 3/4		.7292	8 3/4		.9792	11 3/4
15/64	.234375	2 13/16	31/64	.484375	5 13/16	47/64	.734375	8 13/16	63/64	.984375	11 13/16
	.2396	2 7/8		.4896	5 7/8		.7396	8 7/8		.9896	11 7/8
	.2448	2 15/16		.4948	5 15/16		.7448	8 15/16		.9948	11 15/16
1/4	.2500	3	1/2	.5000	6	3/4	.7500	9	1	1.0000	12

DECIMAL EQUIVALENTS OF B.W.G. AND FRACTIONS FOR STEEL TUBING

B. W. G. OR FRACTION	DECIMAL	B. W. G. OR FRACTION	DECIMAL	B. W. G. OR FRACTION	DECIMAL	B. W. G. OR FRACTION	DECIMAL
36	.004	19	.042	8	.165	7/16	.438
35	.005	3/64	.047	11/64	.172	0000	.454
34	.007	18	.049	7	.180	1/2	.500
33	.008	17	.058	3/16	.188	17/32	.531
32	.009	1/16	.063	13/64	.203	9/16	.563
31	.010	16	.065	6	.203	19/32	.594
30	.012	15	.072	7/32	.219	5/8	.625
29	.013	5/64	.078	5	.220	11/16	.688
28	.014	14	.083	4	.238	3/4	.750
1/64	.016	3/32	.094	1/4	.250	13/16	.813
27	.016	13	.095	3	.259	7/8	.875
26	.018	7/64	.109	9/32	.281	15/16	.938
25	.020	12	.109	2	.284	1	1.000
24	.022	11	.120	1	.300	$1\frac{1}{8}$	1.125
23	.025	1/8	.125	5/16	.313	$1\frac{1}{4}$	1.250
22	.028	10	.134	0	.340	$1\frac{3}{8}$	1.375
1/32	.031	9/64	.141	11/32	.344	$1\frac{1}{2}$	1.500
21	.032	9	.148	3/8	.375	$1\frac{5}{8}$	1.625
20	.035	5/32	.156	00	.380	$1\frac{3}{4}$	1.750
				000	.425	2	2.000

AVERAGE WALL WEIGHT TABLES

Weights shown on the following pages are for either Hot Finished or Cold Drawn Tubing in pounds per foot.

THESE WEIGHTS WERE COMPUTED BY THE FOLLOWING FORMULA:

$$W = 10.68\,(D - t)\,t$$

Where W = Weight in pounds per foot (carried to 4 digits)
D = Outside Diameter in inches (to 3 decimal places)
t = Wall thickness in decimals (to 3 decimal places)

FOR FIGURING THE WEIGHT OF MINIMUM WALL TUBING, USE THE FOLLOWING FORMULA:

$$W = 10.68\left(D - \frac{t}{.875}\right)\frac{t}{.875}$$

WEIGHT TABLE—SEAMLESS STEEL TUBING

1/16" to 5-7/8" Dia. — Wall Thickness—B.W.G. Fraction or Decimal — No. 36 Ga. to 5/64"

Fraction and Decimal Outside Diameter		36	35	34	33	32	31	30	29	28	27	26	25	24	23	22	1/32	21	20	.040	19	.045	3/64	18	.050	.055	17	.060	1/16	16	15	.075	5/64
		.004	.005	.007	.008	.009	.010	.012	.013	.014	.016	.018	.020	.022	.025	.028	.031	.032	.035	.040	.042	.045	.047	.049	.050	.055	.058	.060	.063	.065	.072	.075	.078
1/16	.063	.0025	.0031	.0042	.0047	.0052	.0057	.0065	.0069	.0073	.0080	.0087	.0092	.0096	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
3/32	.094	.0038	.0048	.0065	.0073	.0082	.0090	.0105	.0112	.0120	.0133	.0146	.0158	.0169	.0184	.0197	.0209	.0212	.0221	.0231	.0233	....	....	....	....	....	....	....	....	....	....	....	....
1/8	.125	.0052	.0064	.0088	.0100	.0111	.0123	.0145	.0156	.0166	.0186	.0206	.0224	.0242	.0267	.0290	.0311	.0318	.0336	.0363	.0372	.0384	.0392	.0398	.0401	.0411	.0415	....	....	....	....	....	....
3/16	.188	.0079	.0098	.0135	.0154	.0172	.0190	.0226	.0243	.0260	.0294	.0327	.0359	.0390	.0435	.0478	.0520	.0533	.0572	.0632	.0655	.0687	.0708	.0727	.0737	.0781	.0805	.0820	.0841	.0854	....	....	....
1/4	.250	.0105	.0131	.0182	.0207	.0232	.0256	.0305	.0329	.0353	.0400	.0446	.0491	.0536	.0601	.0664	.0725	.0745	.0804	.0897	.0933	.0985	.1019	.1052	.1068	.1145	.1189	.1218	.1258	.1284	.1369	.1402	.1433
5/16	.313	.0132	.0164	.0229	.0261	.0292	.0324	.0386	.0417	.0447	.0508	.0567	.0626	.0684	.0769	.0852	.0934	.0960	.1039	.1166	.1216	.1288	.1335	.1382	.1404	.1515	.1580	.1621	.1682	.1722	.1853	.1906	.1958
3/8	.375	.0158	.0198	.0275	.0314	.0352	.0390	.0465	.0503	.0540	.0613	.0686	.0758	.0829	.0935	.1038	.1139	.1172	.1271	.1431	.1494	.1586	.1646	.1706	.1736	.1880	.1964	.2019	.2099	.2152	.2330	.2403	.2474
7/16	.438	.0185	.0231	.0322	.0367	.0412	.0457	.0546	.0590	.0634	.0721	.0807	.0893	.0977	.1103	.1226	.1347	.1388	.1506	.1700	.1776	.1889	.1963	.2036	.2072	.2250	.2354	.2422	.2523	.2589	.2814	.2908	.2999
1/2	.500	.0212	.0264	.0369	.0420	.0472	.0523	.0625	.0676	.0727	.0827	.0927	.1025	.1123	.1268	.1411	.1553	.1599	.1738	.1965	.2054	.2187	.2274	.2360	.2403	.2614	.2738	.2820	.2940	.3020	.3291	.3404	.3515
9/16	.563	.0239	.0298	.0416	.0474	.0533	.0591	.0706	.0764	.0821	.0935	.1048	.1160	.1271	.1436	.1600	.1761	.1815	.1974	.2234	.2337	.2490	.2590	.2690	.2739	.2984	.3128	.3223	.3364	.3457	.3776	.3909	.4040
5/8	.625	.0265	.0331	.0462	.0527	.0592	.0657	.0786	.0850	.0914	.1041	.1167	.1292	.1417	.1602	.1785	.1967	.2027	.2205	.2499	.2615	.2787	.2901	.3014	.3071	.3348	.3512	.3621	.3781	.3888	.4252	.4406	.4557
11/16	.688	....	.0365	.0509	.0581	.0653	.0724	.0866	.0937	.1008	.1148	.1288	.1427	.1565	.1770	.1974	.2175	.2242	.2441	.2768	.2898	.3090	.3218	.3344	.3407	.3718	.3902	.4024	.4205	.4325	.4737	.4910	.5082
3/4	.750	....	.0398	.0555	.0634	.0712	.0790	.0946	.1023	.1100	.1254	.1407	.1559	.1711	.1936	.2159	.2380	.2454	.2673	.3033	.3176	.3388	.3529	.3668	.3738	.4082	.4287	.4422	.4622	.4755	.5214	.5407	.5598
13/16	.813	....	.0431	.0603	.0688	.0773	.0858	.1027	.1111	.1195	.1362	.1528	.1694	.1859	.2104	.2347	.2589	.2669	.2908	.3302	.3458	.3691	.3845	.3998	.4074	.4452	.4677	.4825	.5046	.5193	.5698	.5911	.6123
7/8	.875	....	....	.0649	.0741	.0832	.0924	.1106	.1197	.1287	.1468	.1647	.1826	.2004	.2270	.2533	.2794	.2881	.3140	.3567	.3737	.3989	.4156	.4323	.4406	.4817	.5061	.5223	.5463	.5623	.6175	.6408	.6639
15/16	.938	....	....	.0696	.0795	.0893	.0991	.1187	.1284	.1382	.1576	.1769	.1961	.2152	.2438	.2721	.3003	.3096	.3375	.3836	.4019	.4292	.4472	.4652	.4742	.5187	.5451	.5626	.5887	.6060	.6659	.6913	.7164
1	1.000	....	....	....	.0848	.0953	.1057	.1266	.1370	.1474	.1681	.1888	.2093	.2298	.2603	.2907	.3208	.3308	.3607	.4101	.4297	.4590	.4784	.4977	.5073	.5551	.5835	.6024	.6305	.6491	.7136	.7409	.7681
1 1/16	1.063	....	....	....	.0901	.1013	.1125	.1347	.1458	.1568	.1789	.2009	.2228	.2446	.2771	.3095	.3417	.3524	.3843	.4370	.4580	.4893	.5100	.5306	.5409	.5921	.6225	.6427	.6728	.6928	.7620	.7914	.8205
1 1/8	1.125	....	....	....	....	.1073	.1191	.1426	.1544	.1661	.1895	.2128	.2360	.2592	.2937	.3280	.3622	.3735	.4074	.4635	.4858	.5190	.5411	.5631	.5741	.6285	.6609	.6825	.7146	.7359	.8097	.8411	.8722
1 3/16	1.188	....	....	....	....	.1133	.1258	.1507	.1631	.1755	.2003	.2249	.2495	.2740	.3105	.3469	.3831	.3951	.4310	.4904	.5140	.5493	.5727	.5961	.6077	.6655	.7000	.7228	.7569	.7796	.8582	.8915	.9247
1 1/4	1.250	....	....	....	....	....	.1324	.1587	.1717	.1848	.2109	.2368	.2627	.2885	.3271	.3654	.4036	.4163	.4542	.5169	.5419	.5791	.6039	.6285	.6408	.7019	.7384	.7626	.7987	.8226	.9058	.9412	.9763
1 5/16	1.313	....	....	....	....	....	.1392	.1667	.1805	.1942	.2216	.2490	.2762	.3033	.3439	.3843	.4244	.4378	.4777	.5438	.5701	.6094	.6355	.6615	.6744	.7389	.7774	.8029	.8411	.8664	.9543	.9916	1.029
1 3/8	1.375	....	....	....	....	....	....	.1747	.1891	.2035	.2322	.2609	.2894	.3179	.3605	.4028	.4450	.4590	.5009	.5703	.5979	.6392	.6666	.6939	.7076	.7754	.8158	.8427	.8828	.9094	1.002	1.041	1.080
1 7/16	1.438	....	....	....	....	....	....	.1828	.1978	.2129	.2430	.2730	.3029	.3327	.3773	.4216	.4658	.4805	.5244	.5972	.6262	.6695	.6982	.7269	.7412	.8124	.8548	.8830	.9252	.9531	1.050	1.092	1.133
1 1/2	1.500	....	....	....	....	....	....	....	....	.2222	.2536	.2849	.3161	.3473	.3938	.4402	.4864	.5017	.5476	.6237	.6540	.6993	.7293	.7593	.7743	.8488	.8932	.9228	.9669	.9962	1.098	1.141	1.185
1 9/16	1.563	....	....	....	....	....	....	....	....	.2316	.2644	.2970	.3296	.3621	.4106	.4590	.5072	.5232	.5712	.6506	.6823	.7296	.7610	.7923	.8079	.8858	.9323	.9631	1.009	1.040	1.147	1.192	1.237
1 5/8	1.625	....	....	....	....	....	....	....	....	....	....	.3089	.3428	.3766	.4272	.4776	.5277	.5444	.5943	.6771	.7101	.7593	.7921	.8248	.8411	.9222	.9707	1.003	1.051	1.083	1.194	1.242	1.289
1 11/16	1.688	....	....	....	....	....	....	....	....	....	....	.3210	.3563	.3914	.4440	.4964	.5486	.5660	.6179	.7040	.7383	.7896	.8237	.8577	.8747	.9592	1.010	1.043	1.093	1.127	1.243	1.292	1.341
1 3/4	1.750	....	....	....	....	....	....	....	....	....	....	....	....	.4060	.4606	.5149	.5691	.5871	.6411	.7305	.7661	.8194	.8548	.8902	.9078	.9956	1.048	1.083	1.135	1.170	1.290	1.342	1.393
1 13/16	1.813	....	....	....	....	....	....	....	....	....	....	....	....	.4208	.4774	.5338	.5900	.6087	.6646	.7574	.7944	.8497	.8865	.9231	.9414	1.033	1.087	1.123	1.177	1.213	1.339	1.392	1.445
1 7/8	1.875	....	....	....	....	....	....	....	....	....	....	....	....	.4354	.4940	.5523	.6105	.6299	.6878	.7839	.8222	.8795	.9176	.9556	.9746	1.069	1.126	1.163	1.219	1.257	1.386	1.442	1.497
1 15/16	1.938	....	....	....	....	....	....	....	....	....	....	....	....	.4502	.5108	.5712	.6314	.6514	.7113	.8108	.8505	.9098	.9492	.9886	1.008	1.106	1.165	1.203	1.262	1.300	1.435	1.492	1.549
2	2.000	....	....	....	....	....	....	....	....	....	....	....	....	.4648	.5273	.5897	.6519	.6726	.7345	.8373	.8783	.9396	.9803	1.021	1.041	1.142	1.203	1.243	1.303	1.343	1.483	1.542	1.601
2 1/16	2.063	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.6085	.6728	.6941	.7581	.8642	.9065	.9699	1.012	1.054	1.075	1.179	1.242	1.284	1.346	1.387	1.531	1.592	1.654
2 1/8	2.125	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.6271	.6933	.7153	.7812	.8907	.9344	.9996	1.043	1.086	1.108	1.216	1.280	1.323	1.387	1.430	1.579	1.642	1.705
2 3/16	2.188	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.6459	.7141	.7368	.8048	.9176	.9626	1.030	1.075	1.119	1.142	1.253	1.319	1.364	1.430	1.474	1.627	1.693	1.758

2 1/4	2.250															.6645	.7347	.7580	.8280	.9441	.9904	1.060	1.106	1.152	1.175	1.289	1.358	1.403	1.472	1.517	1.675	1.742	1.809
2 5/16	2.313															.6833	.7555	.7796	.8515	.9710	1.019	1.090	1.137	1.185	1.208	1.326	1.397	1.444	1.514	1.561	1.723	1.793	1.862
2 3/8	2.375															.7018	.7761	.8007	.8747	.9975	1.046	1.120	1.169	1.217	1.242	1.363	1.435	1.483	1.556	1.604	1.771	1.842	1.913
2 7/16	2.438															.7207	.7969	.8223	.8982	1.024	1.075	1.150	1.200	1.250	1.275	1.400	1.474	1.524	1.598	1.647	1.819	1.893	1.966
2 1/2	2.500															.7392	.8174	.8435	.9214	1.051	1.103	1.180	1.231	1.283	1.308	1.436	1.513	1.564	1.640	1.690	1.867	1.942	2.018
2 9/16	2.563																		.9450	1.078	1.131	1.210	1.263	1.316	1.342	1.473	1.552	1.604	1.682	1.734	1.915	1.993	2.070
2 5/8	2.625																		.9681	1.104	1.159	1.240	1.294	1.348	1.375	1.510	1.590	1.644	1.724	1.777	1.963	2.043	2.122
2 11/16	2.688																		.9917	1.131	1.187	1.270	1.326	1.381	1.409	1.547	1.629	1.684	1.766	1.821	2.012	2.093	2.174
2 3/4	2.750																		1.015	1.158	1.215	1.300	1.357	1.413	1.442	1.583	1.668	1.724	1.808	1.864	2.059	2.143	2.226
2 13/16	2.813																		1.038	1.185	1.243	1.330	1.388	1.446	1.475	1.620	1.707	1.764	1.850	1.908	2.108	2.193	2.278
2 7/8	2.875																		1.062	1.211	1.271	1.360	1.420	1.479	1.509	1.656	1.745	1.804	1.892	1.951	2.155	2.243	2.330
2 15/16	2.938																		1.085	1.238	1.299	1.390	1.451	1.512	1.542	1.693	1.784	1.844	1.934	1.994	2.204	2.293	2.382
3	3.000																		1.108	1.265	1.327	1.420	1.482	1.544	1.575	1.730	1.822	1.884	1.976	2.037	2.252	2.343	2.434
3 1/16	3.063																		1.132	1.291	1.355	1.450	1.514	1.577	1.609	1.767	1.861	1.924	2.019	2.081	2.300	2.393	2.487
3 1/8	3.125																		1.155	1.318	1.383	1.480	1.545	1.610	1.642	1.803	1.900	1.964	2.060	2.124	2.348	2.443	2.538
3 3/16	3.188																		1.179	1.345	1.411	1.511	1.577	1.643	1.676	1.840	1.939	2.004	2.103	2.168	2.396	2.494	2.591
3 1/4	3.250																		1.202	1.371	1.439	1.540	1.608	1.675	1.709	1.877	1.977	2.044	2.144	2.211	2.444	2.543	2.642
3 5/16	3.313																		1.225	1.398	1.467	1.571	1.639	1.708	1.742	1.914	2.016	2.085	2.187	2.255	2.492	2.594	2.695
3 3/8	3.375																		1.248	1.425	1.495	1.600	1.671	1.741	1.776	1.950	2.055	2.124	2.228	2.298	2.540	2.643	2.747
3 7/16	3.438																		1.272	1.452	1.523	1.631	1.702	1.774	1.809	1.987	2.094	2.165	2.271	2.342	2.588	2.694	2.799
3 1/2	3.500																		1.295	1.478	1.551	1.660	1.733	1.806	1.842	2.024	2.132	2.204	2.313	2.385	2.636	2.743	2.851
3 9/16	3.563																		1.319	1.505	1.579	1.691	1.765	1.839	1.876	2.061	2.171	2.245	2.355	2.428	2.684	2.794	2.903
3 5/8	3.625																		1.342	1.532	1.607	1.721	1.796	1.871	1.909	2.097	2.210	2.284	2.397	2.471	2.732	2.844	2.955
3 11/16	3.688																		1.365	1.558	1.635	1.751	1.828	1.904	1.943	2.134	2.249	2.325	2.439	2.515	2.781	2.894	3.007
3 3/4	3.750																		1.389	1.585	1.663	1.781	1.859	1.937	1.976	2.170	2.287	2.365	2.481	2.558	2.828	2.944	3.059
3 13/16	3.813																		1.412	1.612	1.692	1.811	1.890	1.970	2.009	2.207	2.326	2.405	2.523	2.602	2.877	2.994	3.111
3 7/8	3.875																		1.435	1.638	1.719	1.841	1.922	2.002	2.043	2.244	2.364	2.445	2.565	2.645	2.924	3.044	3.163
3 15/16	3.938																		1.459	1.665	1.748	1.871	1.953	2.035	2.076	2.281	2.403	2.485	2.607	2.689	2.973	3.094	3.216
4	4.000																							2.068	2.109	2.317	2.442	2.525	2.649	2.732	3.020	3.144	3.267
4 1/8	4.125																							2.133	2.176	2.391	2.519	2.605	2.733	2.818	3.117	3.244	3.371
4 1/4	4.250																							2.198	2.243	2.464	2.597	2.685	2.817	2.905	3.213	3.344	3.475
4 3/8	4.375																							2.264	2.310	2.538	2.674	2.765	2.901	2.992	3.309	3.444	3.580
4 1/2	4.500																							2.329	2.376	2.611	2.752	2.845	2.985	3.079	3.405	3.544	3.684
4 5/8	4.625																							2.395	2.443	2.684	2.829	2.925	3.069	3.166	3.501	3.645	3.788
4 3/4	4.750																							2.460	2.510	2.758	2.906	3.005	3.154	3.252	3.597	3.745	3.892
4 7/8	4.875																							2.526	2.577	2.831	2.984	3.085	3.238	3.339	3.693	3.845	3.996
5	5.000																							2.591	2.643	2.905	3.061	3.166	3.322	3.426	3.789	3.945	4.100
5 1/8	5.125																											3.246	3.406	3.513	3.886	4.045	4.204
5 1/4	5.250																											3.326	3.490	3.599	3.982	4.145	4.308
5 3/8	5.375																											3.406	3.574	3.686	4.078	4.245	4.413
5 1/2	5.500																											3.486	3.658	3.773	4.174	4.345	4.517
5 5/8	5.625																												3.742	3.860	4.270	4.446	4.621
5 3/4	5.750																												3.826	3.947	4.366	4.546	4.725
5 7/8	5.875																												3.911	4.033	4.462	4.646	4.829

WEIGHT TABLE—SEAMLESS STEEL TUBING

1/4" to 6-1/2" Dia. — Wall Thickness—B.W.G. Fraction or Decimal — No. 14 Ga. to No. 1 Ga.

Fraction	Decimal Outside Diameter	14	.085	3/32	13	.105	12	.110	11	1/8	10	.135	9/64	9	.150	5/32	8
		.083	.085	.094	.095	.105	.109	.110	.120	.125	.134	.135	.141	.143	.150	.156	.165
1/4	.250	.1480	.1498	.1566	.1573												
5/16	.313	.2039	.2070	.2199	.2212	.2333	.2375	.2385	.2473	.2510	.2562	.2566					
3/8	.375	.2588	.2633	.2821	.2841	.3028	.3097	.3113	.3268	.3338	.3449	.3460	.3524	.3588	.3605	.3649	
7/16	.438	.3147	.3205	.3453	.3480	.3734	.3830	.3853	.4075	.4179	.4351	.4369	.4472	.4584	.4614	.4698	.4811
1/2	.500	.3696	.3767	.4076	.4109	.4430	.4552	.4582	.4870	.5006	.5238	.5263	.5406	.5564	.5607	.5731	.5903
9/16	.563	.4255	.4339	.4708	.4748	.5136	.5285	.5322	.5677	.5847	.6140	.6171	.6355	.6560	.6616	.6781	.7014
5/8	.625	.4805	.4902	.5331	.5377	.5831	.6007	.6050	.6472	.6675	.7027	.7065	.7288	.7540	.7610	.7814	.8106
11/16	.688	.5363	.5474	.5963	.6017	.6538	.6740	.6790	.7279	.7516	.7928	.7973	.8237	.8535	.8619	.8864	.9216
3/4	.750	.5913	.6037	.6586	.6646	.7233	.7462	.7519	.8074	.8344	.8816	.8867	.9171	.9515	.9612	.9897	1.031
13/16	.813	.6471	.6609	.7218	.7285	.7940	.8195	.8259	.8881	.9185	.9717	.9775	1.012	1.051	1.062	1.095	1.142
7/8	.875	.7021	.7172	.7841	.7914	.8635	.8917	.8987	.9676	1.001	1.060	1.067	1.105	1.149	1.161	1.198	1.251
15/16	.938	.7579	.7744	.8473	.8553	.9341	.9651	.9727	1.048	1.085	1.151	1.158	1.200	1.249	1.262	1.303	1.362
1	1.000	.8129	.8306	.9096	.9182	1.004	1.037	1.046	1.128	1.168	1.239	1.247	1.294	1.347	1.362	1.406	1.471
1 1/16	1.063	.8687	.8878	.9728	.9821	1.074	1.111	1.120	1.209	1.252	1.330	1.338	1.388	1.446	1.463	1.511	1.582
1 1/8	1.125	.9237	.9441	1.035	1.045	1.144	1.183	1.192	1.288	1.335	1.418	1.427	1.482	1.544	1.562	1.614	1.692
1 3/16	1.188	.9795	1.001	1.098	1.109	1.214	1.256	1.266	1.369	1.419	1.508	1.518	1.577	1.644	1.663	1.719	1.803
1 1/4	1.250	1.034	1.058	1.161	1.172	1.284	1.328	1.339	1.448	1.502	1.597	1.608	1.670	1.742	1.762	1.823	1.912
1 5/16	1.313	1.090	1.115	1.224	1.236	1.355	1.402	1.413	1.529	1.586	1.687	1.698	1.765	1.841	1.863	1.928	2.023
1 3/8	1.375	1.145	1.171	1.286	1.299	1.424	1.474	1.486	1.608	1.669	1.776	1.788	1.858	1.939	1.962	2.031	2.132
1 7/16	1.438	1.201	1.228	1.349	1.363	1.495	1.547	1.560	1.689	1.753	1.866	1.879	1.953	2.039	2.063	2.136	2.243
1 1/2	1.500	1.256	1.285	1.412	1.426	1.564	1.619	1.633	1.769	1.836	1.955	1.968	2.046	2.137	2.163	2.239	2.353
1 9/16	1.563	1.312	1.342	1.475	1.489	1.635	1.693	1.707	1.849	1.920	2.045	2.059	2.141	2.237	2.264	2.344	2.464
1 5/8	1.625	1.367	1.398	1.537	1.552	1.705	1.765	1.780	1.929	2.003	2.134	2.148	2.235	2.335	2.363	2.447	2.573
1 11/16	1.688	1.423	1.455	1.600	1.616	1.775	1.838	1.854	2.010	2.087	2.224	2.239	2.330	2.434	2.464	2.552	2.684
1 3/4	1.750	1.478	1.511	1.662	1.679	1.845	1.910	1.927	2.089	2.169	2.313	2.329	2.423	2.532	2.563	2.656	2.793
1 13/16	1.813	1.534	1.569	1.726	1.743	1.915	1.984	2.001	2.170	2.253	2.403	2.419	2.518	2.632	2.664	2.761	2.904
1 7/8	1.875	1.589	1.625	1.788	1.806	1.985	2.056	2.074	2.249	2.336	2.492	2.509	2.611	2.730	2.763	2.864	3.013
1 15/16	1.938	1.644	1.682	1.851	1.870	2.056	2.129	2.148	2.330	2.420	2.582	2.600	2.706	2.829	2.864	2.969	3.124
2	2.000	1.699	1.738	1.913	1.933	2.125	2.201	2.220	2.409	2.503	2.670	2.689	2.799	2.927	2.964	3.072	3.234
2 1/16	2.063	1.755	1.796	1.977	1.997	2.196	2.275	2.294	2.490	2.587	2.761	2.780	2.894	3.027	3.065	3.177	3.345
2 1/8	2.125	1.810	1.852	2.039	2.060	2.265	2.347	2.367	2.570	2.670	2.849	2.869	2.988	3.125	3.164	3.281	3.454
2 3/16	2.188	1.866	1.909	2.102	2.124	2.336	2.420	2.441	2.650	2.754	2.940	2.960	3.083	3.225	3.265	3.385	3.565
2 1/4	2.250	1.921	1.965	2.164	2.186	2.405	2.492	2.514	2.730	2.837	3.028	3.049	3.176	3.323	3.364	3.489	3.674
2 5/16	2.313	1.977	2.023	2.228	2.250	2.476	2.566	2.588	2.811	2.921	3.118	3.140	3.271	3.422	3.465	3.594	3.785
2 3/8	2.375	2.032	2.079	2.290	2.313	2.546	2.638	2.661	2.890	3.004	3.207	3.230	3.364	3.520	3.564	3.697	3.894
2 7/16	2.438	2.088	2.136	2.353	2.377	2.616	2.711	2.735	2.971	3.088	3.297	3.320	3.459	3.620	3.665	3.802	4.005

Fraction	Decimal Outside Diameter	11/64	7	3/16	.200	6	7/32	5	4	.240	1/4	3	.260	.280	9/32	2	1
		.172	.180	.188	.200	.203	.219	.220	.238	.240	.250	.259	.260	.280	.281	.284	.300
1/4	.250																
5/16	.313																
3/8	.375																
7/16	.438	.4886															
1/2	.500	.6025	.6152	.6264													
9/16	.563	.7183	.7363	.7529													
5/8	.625	.8321	.8555	.8774	.9078	.9149	.9496										
11/16	.688	.9479	.9766	1.004	1.042	1.051	1.097										
3/4	.750	1.062	1.096	1.128	1.175	1.186	1.242	1.245	1.301	1.307	1.335						
13/16	.813	1.177	1.217	1.255	1.309	1.323	1.389	1.393	1.462	1.469	1.503						
7/8	.875	1.291	1.336	1.379	1.442	1.457	1.534	1.539	1.619	1.628	1.669	1.704	1.708	1.779	1.783	1.793	1.842
15/16	.938	1.407	1.457	1.506	1.576	1.594	1.682	1.687	1.779	1.789	1.837	1.878	1.883	1.968	1.972	1.984	2.044
1	1.000	1.521	1.576	1.630	1.709	1.728	1.827	1.833	1.937	1.948	2.003	2.050	2.055	2.153	2.158	2.172	2.243
1 1/16	1.063	1.637	1.697	1.757	1.843	1.865	1.974	1.981	2.097	2.110	2.171	2.224	2.230	2.341	2.347	2.363	2.445
1 1/8	1.125	1.751	1.817	1.881	1.976	1.999	2.119	2.126	2.255	2.268	2.336	2.395	2.402	2.527	2.533	2.551	2.643
1 3/16	1.188	1.866	1.938	2.008	2.110	2.136	2.266	2.274	2.415	2.430	2.504	2.570	2.577	2.715	2.722	2.742	2.845
1 1/4	1.250	1.980	2.057	2.132	2.243	2.270	2.411	2.420	2.572	2.589	2.670	2.741	2.749	2.901	2.908	2.930	3.044
1 5/16	1.313	2.096	2.178	2.259	2.377	2.407	2.559	2.568	2.732	2.750	2.838	2.915	2.924	3.089	3.097	3.121	3.246
1 3/8	1.375	2.210	2.297	2.383	2.510	2.541	2.704	2.714	2.890	2.909	3.004	3.087	3.096	3.274	3.283	3.309	3.444
1 7/16	1.438	2.326	2.418	2.510	2.644	2.678	2.851	2.862	3.050	3.071	3.172	3.261	3.271	3.463	3.472	3.500	3.646
1 1/2	1.500	2.439	2.538	2.634	2.777	2.812	2.996	3.007	3.208	3.230	3.338	3.433	3.443	3.648	3.658	3.688	3.845
1 9/16	1.563	2.555	2.659	2.761	2.911	2.949	3.144	3.156	3.368	3.391	3.506	3.607	3.618	3.837	3.847	3.879	4.047
1 5/8	1.625	2.669	2.778	2.885	3.044	3.083	3.289	3.301	3.526	3.550	3.671	3.779	3.790	4.022	4.033	4.067	4.245
1 11/16	1.688	2.785	2.899	3.012	3.178	3.220	3.436	3.449	3.686	3.712	3.839	3.953	3.965	4.210	4.223	4.259	4.447
1 3/4	1.750	2.899	3.018	3.136	3.311	3.354	3.581	3.595	3.843	3.870	4.005	4.124	4.137	4.396	4.409	4.447	4.646
1 13/16	1.813	3.014	3.139	3.263	3.445	3.491	3.728	3.743	4.003	4.032	4.173	4.299	4.312	4.584	4.598	4.638	4.848
1 7/8	1.875	3.128	3.258	3.387	3.578	3.625	3.873	3.889	4.161	4.191	4.339	4.470	4.485	4.770	4.784	4.826	5.046
1 15/16	1.938	3.244	3.380	3.514	3.712	3.762	4.021	4.037	4.321	4.352	4.507	4.644	4.659	4.958	4.973	5.017	5.248
2	2.000	3.358	3.499	3.638	3.845	3.896	4.166	4.182	4.479	4.511	4.673	4.816	4.832	5.143	5.159	5.205	5.447
2 1/16	2.063	3.474	3.620	3.765	3.979	4.033	4.313	4.330	4.639	4.673	4.841	4.990	5.007	5.332	5.348	5.396	5.649
2 1/8	2.125	3.588	3.739	3.889	4.112	4.167	4.458	4.476	4.796	4.832	5.006	5.162	5.179	5.517	5.534	5.584	5.847
2 3/16	2.188	3.703	3.860	4.016	4.246	4.304	4.605	4.624	4.957	4.993	5.174	5.336	5.354	5.706	5.723	5.775	6.049
2 1/4	2.250	3.817	3.979	4.140	4.379	4.438	4.750	4.770	5.114	5.152	5.340	5.507	5.526	5.891	5.909	5.963	6.248
2 5/16	2.313	3.933	4.100	4.267	4.513	4.575	4.898	4.918	5.274	5.314	5.508	5.682	5.701	6.079	6.098	6.154	6.450
2 3/8	2.375	4.047	4.220	4.391	4.646	4.709	5.043	5.063	5.432	5.472	5.674	5.853	5.873	6.265	6.284	6.342	6.648
2 7/16	2.438	4.163	4.341	4.518	4.780	4.846	5.190	5.211	5.592	5.634	5.842	6.027	6.048	6.453	6.473	6.533	6.850

2 1/2	2.500	2.143	2.192	2.415	2.440	2.686	2.783	2.808	3.050	3.171	3.386	3.410	3.552	3.718	3.765	3.905	4.115	4.276	4.460	4.642	4.913	4.980	5.335	5.357	5.750	5.793	6.008	6.199	6.220	6.639	6.659	6.721	7.049
2 9/16	2.563	2.198	2.250	2.479	2.504	2.756	2.857	2.882	3.131	3.255	3.476	3.501	3.647	3.817	3.866	4.010	4.226	4.392	4.581	4.769	5.047	5.117	5.482	5.505	5.910	5.954	6.176	6.373	6.395	6.827	6.848	6.912	7.251
2 5/8	2.625	2.253	2.306	2.541	2.567	2.826	2.929	2.955	3.210	3.338	3.565	3.590	3.741	3.915	3.965	4.114	4.335	4.506	4.700	4.893	5.180	5.251	5.627	5.651	6.067	6.113	6.341	6.545	6.567	7.012	7.035	7.101	7.449
2 11/16	2.688	2.309	2.363	2.604	2.631	2.897	3.002	3.029	3.291	3.422	3.655	3.681	3.835	4.015	4.066	4.219	4.446	4.622	4.821	5.020	5.314	5.388	5.775	5.799	6.228	6.275	6.509	6.719	6.742	7.201	7.224	7.292	7.651
2 3/4	2.750	2.364	2.419	2.666	2.694	2.966	3.074	3.101	3.371	3.504	3.744	3.770	3.929	4.113	4.165	4.322	4.555	4.736	4.941	5.144	5.447	5.522	5.920	5.944	6.385	6.434	6.675	6.890	6.914	7.386	7.410	7.480	7.850
2 13/16	2.813	2.420	2.476	2.730	2.758	3.037	3.148	3.175	3.451	3.588	3.834	3.861	4.024	4.212	4.266	4.427	4.666	4.851	5.062	5.271	5.581	5.659	6.067	6.093	6.545	6.595	6.843	7.065	7.089	7.575	7.599	7.671	8.052
2 7/8	2.875	2.475	2.533	2.792	2.821	3.106	3.220	3.248	3.531	3.671	3.923	3.951	4.117	4.310	4.365	4.530	4.776	4.965	5.181	5.395	5.714	5.793	6.212	6.238	6.703	6.754	7.009	7.236	7.261	7.760	7.785	7.859	8.250
2 15/16	2.938	2.531	2.590	2.855	2.885	3.177	3.293	3.322	3.612	3.755	4.013	4.041	4.212	4.410	4.466	4.635	4.887	5.081	5.302	5.522	5.848	5.930	6.360	6.386	6.863	6.916	7.177	7.410	7.436	7.948	7.974	8.050	8.452
3	3.000	2.586	2.646	2.917	2.947	3.246	3.365	3.395	3.691	3.838	4.102	4.131	4.305	4.508	4.566	4.738	4.996	5.195	5.421	5.646	5.981	6.064	6.505	6.532	7.021	7.074	7.343	7.582	7.608	8.134	8.160	8.238	8.651
3 1/16	3.063	2.642	2.703	2.981	3.011	3.317	3.439	3.469	3.772	3.922	4.192	4.222	4.400	4.608	4.667	4.843	5.107	5.311	5.542	5.773	6.115	6.201	6.652	6.680	7.181	7.236	7.511	7.756	7.783	8.322	8.349	8.429	8.853
3 1/8	3.125	2.697	2.760	3.043	3.074	3.387	3.511	3.542	3.851	4.005	4.280	4.311	4.494	4.706	4.766	4.947	5.216	5.425	5.661	5.897	6.248	6.335	6.797	6.826	7.338	7.395	7.676	7.928	7.956	8.508	8.535	8.617	9.051
3 3/16	3.188	2.752	2.817	3.106	3.138	3.457	3.584	3.616	3.932	4.089	4.371	4.402	4.588	4.805	4.867	5.052	5.327	5.540	5.783	6.024	6.382	6.472	6.944	6.974	7.498	7.556	7.844	8.102	8.130	8.696	8.724	8.808	9.253
3 1/4	3.250	2.807	2.873	3.168	3.201	3.527	3.657	3.689	4.011	4.172	4.459	4.491	4.682	4.903	4.966	5.155	5.436	5.654	5.902	6.148	6.515	6.606	7.089	7.119	7.656	7.715	8.010	8.273	8.303	8.881	8.910	8.996	9.452
3 5/16	3.313	2.863	2.930	3.232	3.265	3.597	3.730	3.763	4.092	4.256	4.550	4.582	4.777	5.003	5.067	5.260	5.547	5.770	6.023	6.275	6.649	6.743	7.237	7.267	7.816	7.877	8.178	8.448	8.478	9.070	9.099	9.187	9.654
3 3/8	3.375	2.918	2.987	3.294	3.328	3.667	3.802	3.836	4.172	4.339	4.638	4.671	4.870	5.101	5.166	5.363	5.657	5.884	6.142	6.399	6.782	6.877	7.382	7.413	7.974	8.036	8.344	8.619	8.650	9.255	9.285	9.375	9.852
3 7/16	3.438	2.974	3.044	3.357	3.392	3.738	3.875	3.910	4.252	4.423	4.728	4.762	4.965	5.200	5.267	5.468	5.768	6.000	6.263	6.525	6.916	7.014	7.529	7.561	8.134	8.197	8.512	8.793	8.825	9.444	9.474	9.566	10.05
3 1/2	3.500	3.029	3.100	3.419	3.455	3.807	3.948	3.983	4.332	4.506	4.817	4.852	5.058	5.298	5.367	5.571	5.877	6.113	6.382	6.650	7.049	7.148	7.674	7.707	8.291	8.356	8.678	8.965	8.997	9.629	9.660	9.755	10.25
3 9/16	3.563	3.085	3.157	3.483	3.519	3.878	4.021	4.057	4.413	4.590	4.907	4.942	5.153	5.398	5.468	5.676	5.988	6.229	6.503	6.776	7.183	7.285	7.821	7.855	8.452	8.518	8.846	9.139	9.172	9.817	9.850	9.946	10.45
3 5/8	3.625	3.140	3.214	3.545	3.582	3.947	4.093	4.129	4.492	4.673	4.996	5.032	5.246	5.496	5.567	5.780	6.097	6.343	6.623	6.901	7.316	7.419	7.966	8.000	8.609	8.676	9.011	9.311	9.344	10.00	10.04	10.13	10.65
3 11/16	3.688	3.196	3.271	3.608	3.645	4.018	4.166	4.203	4.573	4.757	5.086	5.123	5.341	5.595	5.668	5.885	6.208	6.459	6.744	7.027	7.450	7.556	8.114	8.148	8.769	8.838	9.179	9.485	9.519	10.19	10.22	10.32	10.86
3 3/4	3.750	3.251	3.327	3.670	3.708	4.088	4.239	4.276	4.652	4.839	5.175	5.212	5.435	5.693	5.767	5.988	6.317	6.573	6.863	7.152	7.583	7.690	8.259	8.294	8.927	8.997	9.345	9.657	9.691	10.38	10.41	10.51	11.05
3 13/16	3.813	3.306	3.384	3.734	3.772	4.158	4.312	4.350	4.733	4.923	5.265	5.303	5.530	5.793	5.868	6.093	6.429	6.688	6.984	7.278	7.717	7.827	8.406	8.442	9.087	9.158	9.513	9.831	9.866	10.57	10.60	10.70	11.26
3 7/8	3.875	3.361	3.441	3.796	3.835	4.228	4.384	4.423	4.812	5.006	5.354	5.392	5.623	5.891	5.967	6.196	6.538	6.802	7.103	7.403	7.850	7.961	8.551	8.588	9.245	9.317	9.679	10.00	10.04	10.75	10.79	10.89	11.45
3 15/16	3.938	3.417	3.498	3.859	3.899	4.298	4.457	4.497	4.893	5.090	5.444	5.483	5.718	5.991	6.068	6.301	6.649	6.918	7.224	7.529	7.984	8.098	8.698	8.736	9.405	9.479	9.847	10.18	10.21	10.94	10.97	11.08	11.66
4	4.000	3.472	3.554	3.921	3.962	4.368	4.530	4.570	4.973	5.173	5.533	5.573	5.811	6.089	6.168	6.404	6.758	7.032	7.344	7.654	8.117	8.232	8.843	8.881	9.562	9.638	10.01	10.35	10.39	11.12	11.16	11.27	11.85
4 1/8	4.125	3.583	3.668	4.047	4.089	4.508	4.675	4.717	5.133	5.340	5.712	5.753	5.999	6.286	6.368	6.613	6.978	7.262	7.584	7.905	8.384	8.503	9.136	9.175	9.880	9.958	10.35	10.69	10.73	11.50	11.54	11.65	12.26
4 1/4	4.250	3.694	3.781	4.172	4.216	4.648	4.821	4.864	5.293	5.507	5.890	5.933	6.188	6.484	6.568	6.821	7.199	7.491	7.824	8.156	8.651	8.774	9.428	9.469	10.20	10.28	10.68	11.04	11.08	11.87	11.91	12.03	12.66
4 3/8	4.375	3.805	3.894	4.298	4.342	4.788	4.966	5.011	5.453	5.674	6.069	6.113	6.376	6.681	6.768	7.029	7.419	7.721	8.064	8.407	8.918	9.045	9.721	9.763	10.52	10.60	11.01	11.39	11.43	12.25	12.29	12.41	13.06
4 1/2	4.500	3.915	4.008	4.423	4.469	4.929	5.112	5.157	5.613	5.841	6.248	6.293	6.564	6.879	6.969	7.237	7.639	7.950	8.305	8.658	9.185	9.316	10.01	10.06	10.83	10.92	11.35	11.73	11.77	12.62	12.66	12.79	13.46
4 5/8	4.625	4.026	4.121	4.549	4.596	5.069	5.257	5.304	5.774	6.008	6.427	6.474	6.752	7.077	7.169	7.446	7.859	8.180	8.545	8.909	9.452	9.587	10.31	10.35	11.15	11.24	11.68	12.08	12.12	12.99	13.04	13.17	13.86
4 3/4	4.750	4.137	4.235	4.674	4.723	5.209	5.403	5.451	5.934	6.174	6.606	6.654	6.941	7.274	7.369	7.654	8.080	8.410	8.785	9.160	9.719	9.858	10.60	10.64	11.47	11.56	12.02	12.42	12.47	13.37	13.42	13.55	14.26
4 7/8	4.875	4.248	4.348	4.800	4.850	5.349	5.548	5.598	6.094	6.341	6.785	6.834	7.129	7.472	7.569	7.862	8.300	8.639	9.026	9.411	9.986	10.13	10.89	10.94	11.79	11.88	12.35	12.77	12.81	13.74	13.79	13.93	14.66
5	5.000	4.359	4.462	4.925	4.977	5.489	5.694	5.745	6.254	6.508	6.964	7.014	7.317	7.669	7.770	8.070	8.520	8.869	9.266	9.662	10.25	10.40	11.18	11.23	12.10	12.20	12.68	13.11	13.16	14.11	14.16	14.30	15.06
5 1/8	5.125	4.469	4.575	5.051	5.103	5.629	5.839	5.892	6.414	6.675	7.143	7.195	7.505	7.867	7.970	8.279	8.741	9.098	9.506	9.913	10.52	10.67	11.47	11.52	12.42	12.52	13.02	13.46	13.51	14.49	14.54	14.68	15.46
5 1/4	5.250	4.580	4.689	5.176	5.230	5.770	5.985	6.038	6.575	6.842	7.322	7.375	7.694	8.064	8.170	8.487	8.961	9.328	9.747	10.16	10.79	10.94	11.77	11.82	12.74	12.84	13.35	13.81	13.86	14.86	14.91	15.06	15.86
5 3/8	5.375	4.691	4.802	5.302	5.357	5.910	6.130	6.185	6.735	7.009	7.500	7.555	7.882	8.262	8.370	8.695	9.181	9.558	9.987	10.41	11.05	11.21	12.06	12.11	13.06	13.16	13.68	14.15	14.20	15.24	15.29	15.44	16.26
5 1/2	5.500	4.802	4.916	5.427	5.484	6.050	6.276	6.332	6.895	7.176	7.679	7.735	8.070	8.460	8.571	8.904	9.401	9.787	10.23	10.67	11.32	11.48	12.35	12.41	13.38	13.48	14.02	14.50	14.55	15.61	15.66	15.82	16.66
5 5/8	5.625	4.913	5.029	5.553	5.611	6.190	6.421	6.479	7.055	7.343	7.858	7.915	8.258	8.657	8.771	9.112	9.622	10.02	10.47	10.92	11.59	11.76	12.64	12.70	13.69	13.80	14.35	14.84	14.90	15.98	16.04	16.20	17.06
5 3/4	5.750	5.023	5.143	5.678	5.738	6.330	6.567	6.626	7.215	7.509	8.037	8.096	8.446	8.855	8.971	9.320	9.842	10.25	10.71	11.17	11.85	12.03	12.94	12.99	14.01	14.12	14.69	15.19	15.24	16.36	16.41	16.58	17.46
5 7/8	5.875	5.134	5.256	5.804	5.864	6.470	6.712	6.773	7.376	7.676	8.216	8.276	8.635	9.052	9.171	9.528	10.06	10.48	10.95	11.42	12.12	12.30	13.23	13.29	14.33	14.44	15.02	15.53	15.59	16.73	16.79	16.96	17.86
6	6.000	5.245	5.370	5.929	5.991	6.611	6.858	6.920	7.536	7.843	8.395	8.456	8.823	9.250	9.372	9.737	10.28	10.71	11.19	11.67	12.39	12.57	13.52	13.58	14.65	14.76	15.35	15.88	15.94	17.11	17.16	17.34	18.26
6 1/8	6.125	5.356	5.483	6.055	6.118	6.751	7.003	7.066	7.696	8.010	8.574	8.636	9.011	9.447	9.572	9.945	10.50	10.94	11.43	11.92	12.66	12.84	13.81	13.87	14.96	15.08	15.69	16.23	16.29	17.48	17.54	17.72	18.66
6 1/4	6.250	5.467	5.597	6.180	6.245	6.891	7.149	7.213	7.856	8.177	8.753	8.817	9.199	9.645	9.772	10.15	10.72	11.17	11.67	12.17	12.92	13.11	14.11	14.17	15.28	15.40	16.02	16.57	16.63	17.85	17.91	18.10	19.06
6 3/8	6.375	.....	.....	.....	.....	7.031	7.294	7.360	8.016	8.344	8.932	8.997	9.388	9.843	9.972	10.36	10.94	11.39	11.91	12.42	13.19	13.38	14.40	14.46	15.60	15.73	16.35	16.92	16.98	18.23	18.29	18.47	19.46
6 1/2	6.500	.....	.....	.....	.....	7.171	7.440	7.507	8.177	8.511	9.111	9.177	9.576	10.04	10.17	10.57	11.16	11.62	12.15	12.67	13.46	13.65	14.69	14.76	15.92	16.05	16.69	17.26	17.33	18.60	18.66	18.85	19.86

WEIGHT TABLE—SEAMLESS STEEL TUBING

6-5/8" to 14-3/8" — Wall Thickness—B.W.G. Fraction or Decimal — No. 14 Ga. to No. 1 Ga.

Fraction and Decimal Outside Diameter		14	.085	3/32	13	.105	12	.110	11	1/8	10	.135	9/64	9	.150	5/32	8	11/64	7	3/16	.200	6	7/32	5	4	.240	1/4	3	.260	.280	9/32	2	1
		.083	.085	.094	.095	.105	.109	.110	.120	.125	.134	.135	.141	.148	.150	.156	.165	.172	.180	.188	.200	.203	.219	.220	.238	.240	.250	.259	.260	.280	.281	.284	.300
6 5/8	6.625					7.312	7.585	7.654	8.337	8.678	9.289	9.357	9.764	10.24	10.37	10.78	11.38	11.85	12.39	12.92	13.72	13.92	14.98	15.05	16.23	16.37	17.02	17.61	17.67	18.97	19.04	19.23	20.27
6 3/4	6.750										9.468	9.538	9.952	10.44	10.57	10.99	11.60	12.08	12.63	13.18	13.99	14.19	15.28	15.34	16.55	16.69	17.36	17.95	18.02	19.35	19.41	19.61	20.67
6 7/8	6.875										9.647	9.718	10.14	10.63	10.77	11.19	11.82	12.31	12.87	13.43	14.26	14.47	15.57	15.64	16.87	17.01	17.69	18.30	18.37	19.72	19.79	19.99	21.07
7	7.000													10.83	10.97	11.40	12.04	12.54	13.11	13.68	14.52	14.74	15.86	15.93	17.19	17.33	18.02	18.65	18.72	20.10	20.16	20.37	21.47
7 1/8	7.125													11.03	11.17	11.61	12.26	12.77	13.35	13.93	14.79	15.01	16.15	16.22	17.51	17.65	18.36	18.99	19.06	20.47	20.54	20.75	21.87
7 1/4	7.250													11.23	11.37	11.82	12.49	13.00	13.59	14.18	15.06	15.28	16.44	16.52	17.82	17.97	18.69	19.34	19.41	20.84	20.91	21.13	22.27
7 3/8	7.375													11.42	11.57	12.03	12.71	13.23	13.83	14.43	15.33	15.55	16.74	16.81	18.14	18.29	19.02	19.68	19.76	21.22	21.29	21.51	22.67
7 1/2	7.500																			14.68	15.59	15.82	17.03	17.11	18.46	18.61	19.36	20.03	20.10	21.59	21.66	21.89	23.07
7 5/8	7.625																			14.93	15.86	16.09	17.32	17.40	18.78	18.93	19.69	20.38	20.45	21.96	22.04	22.27	23.47
7 3/4	7.750																			15.18	16.13	16.36	17.61	17.69	19.09	19.25	20.03	20.72	20.80	22.34	22.42	22.65	23.87
8	8.000																			15.69	16.66	16.90	18.20	18.28	19.73	19.89	20.69	21.41	21.49	23.09	23.17	23.40	24.67
8 1/4	8.250																				17.19	17.45	18.78	18.87	20.37	20.53	21.36	22.10	22.19	23.83	23.92	24.16	25.47
8 1/2	8.500																				17.73	17.99	19.37	19.45	21.00	21.17	22.03	22.80	22.88	24.58	24.67	24.92	26.27
8 5/8	8.625																				18.00	18.26	19.66	19.75	21.32	21.49	22.36	23.14	23.23	24.95	25.04	25.30	26.67
8 3/4	8.750																						19.95	20.04	21.64	21.81	22.70	23.49	23.58	25.33	25.42	25.68	27.07
9	9.000																						20.54	20.63	22.27	22.45	23.36	24.18	24.27	26.08	26.17	26.44	27.87
9 1/4	9.250																							21.22	22.91	23.09	24.03	24.87	24.96	26.82	26.92	27.19	28.68
9 1/2	9.500																							21.80	23.54	23.74	24.70	25.56	25.66	27.57	27.67	27.95	29.48
9 5/8	9.625																							22.10	23.86	24.06	25.03	25.91	26.00	27.95	28.04	28.33	29.88
9 3/4	9.750																							22.39	24.18	24.38	25.37	26.25	26.35	28.32	28.42	28.71	30.28
10	10.000																							22.98	24.81	25.02	26.03	26.94	27.05	29.07	29.17	29.47	31.08
10 1/4	10.250																							23.57	25.45	25.66	26.70	27.64	27.74	29.81	29.92	30.23	31.88
10 1/2	10.500																							24.15	26.08	26.30	27.37	28.33	28.43	30.56	30.67	30.99	32.68
10 3/4	10.750																							24.74	26.72	26.94	28.04	29.02	29.13	31.31	31.42	31.74	33.48
11	11.000																											29.71	29.82	32.06	32.17	32.50	34.28
11 1/4	11.250																											30.40	30.52	32.80	32.92	33.26	35.08
11 1/2	11.500																											31.09	31.21	33.55	33.67	34.02	35.88
11 3/4	11.750																											31.79	31.91	34.30	34.42	34.78	36.69
12	12.000																											32.48	32.60	35.05	35.17	35.54	37.49
12 1/4	12.250																											33.17	33.29	35.80	35.92	36.29	38.29
12 1/2	12.500																											33.86	33.99	36.54	36.67	37.05	39.09
12 3/4	12.750																											34.55	34.68	37.29	37.42	37.81	39.89
13	13.000																											35.24	35.38	38.04	38.17	38.57	40.69
13 1/4	13.250																											35.93	36.07	38.79	38.92	39.33	41.49
13 1/2	13.500																											36.63	36.76	39.53	39.67	40.09	42.29
13 3/4	13.750																											37.32	37.46	40.28	40.42	40.84	43.09
14	14.000																											38.01	38.15	41.03	41.17	41.60	43.89
14 1/4	14.250																											38.70	38.85	41.78	41.92	42.36	44.70
14 3/8	14.375																											39.05	39.19	42.15	42.30	42.74	45.10

7/8" to 3-1/16" Dia. **Wall Thickness—B.W.G. Fraction or Decimal** 5/16" to 2"

Fraction and Decimal Outside Diameter		5/16	.320	0	11/32	.360	3/8	00	.400	.420	7/16	.440	.460	.480	1/2	17/32	9/16	19/32	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	2
		.313	.320	.340	.344	.360	.375	.380	.400	.420	.438	.440	.460	.480	.500	.531	.563	.594	.625	.688	.750	.813	.875	.938	1.000	1.125	1.250	1.375	1.500	1.625	1.750	2.000
7/8	.875	1.879																														
15/16	.938	2.089																														
1	1.000	2.297	2.324	2.397	2.410	2.461	2.503																									
1 1/16	1.063	2.507	2.539	2.625	2.642	2.703	2.755																									
1 1/8	1.125	2.714	2.751	2.850	2.869	2.941	3.004																									
1 3/16	1.188	2.925	2.966	3.079	3.101	3.183	3.256	3.279																								
1 1/4	1.250	3.132	3.178	3.304	3.329	3.422	3.504	3.531	3.631																							
1 5/16	1.313	3.343	3.394	3.533	3.560	3.664	3.757	3.786	3.900																							
1 3/8	1.375	3.550	3.606	3.758	3.788	3.902	4.005	4.038	4.165	4.284	4.383	4.394	4.495	4.588	4.673																	
1 7/16	1.438	3.761	3.821	3.987	4.019	4.145	4.257	4.294	4.434	4.566	4.678	4.690	4.805	4.911	5.009																	
1 1/2	1.500	3.968	4.033	4.212	4.247	4.383	4.506	4.545	4.699	4.844	4.968	4.981	5.109	5.229	5.340	5.495	5.634															
1 9/16	1.563	4.179	4.248	4.441	4.479	4.625	4.758	4.801	4.968	5.127	5.263	5.277	5.419	5.552	5.676	5.853	6.013	6.147	6.261													
1 5/8	1.625	4.386	4.460	4.666	4.706	4.864	5.006	5.053	5.233	5.405	5.553	5.569	5.723	5.870	6.008	6.204	6.386	6.541	6.675													
1 11/16	1.688	4.596	4.675	4.895	4.938	5.106	5.259	5.308	5.502	5.688	5.847	5.865	6.033	6.193	6.344	6.561	6.764	6.940	7.096													
1 3/4	1.750	4.804	4.887	5.120	5.166	5.344	5.507	5.560	5.767	5.966	6.137	6.156	6.338	6.511	6.675	6.913	7.137	7.334	7.509	7.803												
1 13/16	1.813	5.014	5.102	5.349	5.397	5.586	5.759	5.816	6.036	6.248	6.432	6.452	6.647	6.833	7.011	7.270	7.516	7.733	7.930	8.266												
1 7/8	1.875	5.222	5.314	5.574	5.625	5.825	6.008	6.067	6.301	6.527	6.722	6.743	6.952	7.151	7.343	7.622	7.889	8.127	8.344	8.722												
1 15/16	1.938	5.432	5.530	5.803	5.856	6.067	6.260	6.323	6.570	6.809	7.017	7.039	7.261	7.474	7.679	7.979	8.268	8.526	8.764	9.185	9.516											
2	2.000	5.639	5.742	6.028	6.084	6.305	6.508	6.575	6.835	7.087	7.307	7.331	7.566	7.792	8.010	8.331	8.640	8.920	9.178	9.640	10.01											
2 1/16	2.063	5.850	5.957	6.257	6.315	6.548	6.760	6.830	7.104	7.370	7.601	7.627	7.875	8.115	8.346	8.688	9.019	9.319	9.599	10.10	10.52											
2 1/8	2.125	6.057	6.169	6.482	6.543	6.786	7.009	7.082	7.369	7.648	7.892	7.918	8.180	8.433	8.678	9.040	9.392	9.713	10.01	10.56	11.01											
2 3/16	2.188	6.268	6.384	6.710	6.775	7.028	7.261	7.338	7.638	7.931	8.186	8.214	8.489	8.756	9.014	9.397	9.771	10.11	10.43	11.02	11.52											
2 1/4	2.250	6.475	6.596	6.936	7.002	7.267	7.509	7.589	7.903	8.209	8.476	8.506	8.794	9.074	9.345	9.749	10.14	10.51	10.85	11.48	12.02											
2 5/16	2.313	6.686	6.811	7.164	7.234	7.509	7.762	7.845	8.172	8.491	8.771	8.802	9.103	9.397	9.681	10.11	10.52	10.91	11.27	11.94	12.52											
2 3/8	2.375	6.893	7.023	7.389	7.462	7.747	8.010	8.097	8.437	8.769	9.061	9.093	9.408	9.715	10.01	10.46	10.90	11.30	11.68	12.40	13.02	13.56	14.02									
2 7/16	2.438	7.104	7.238	7.618	7.693	7.989	8.262	8.352	8.706	9.052	9.356	9.389	9.718	10.04	10.35	10.81	11.27	11.70	12.10	12.86	13.52	14.11	14.61									
2 1/2	2.500	7.311	7.450	7.843	7.921	8.228	8.511	8.604	8.971	9.330	9.646	9.680	10.02	10.36	10.68	11.17	11.65	12.09	12.52	13.31	14.02	14.65	15.19									
2 9/16	2.563	7.521	7.666	8.072	8.152	8.470	8.763	8.859	9.240	9.613	9.940	9.976	10.33	10.68	11.02	11.52	12.03	12.49	12.94	13.78	14.52	15.19	15.77	16.28								
2 5/8	2.625	7.729	7.878	8.297	8.380	8.708	9.011	9.111	9.505	9.891	10.23	10.27	10.64	11.00	11.35	11.88	12.40	12.88	13.35	14.23	15.02	15.73	16.35	16.90								
2 11/16	2.688	7.939	8.093	8.526	8.612	8.951	9.264	9.367	9.774	10.17	10.53	10.56	10.95	11.32	11.68	12.23	12.78	13.28	13.77	14.70	15.52	16.28	16.94	17.53								
2 3/4	2.750	8.147	8.305	8.751	8.839	9.189	9.512	9.618	10.04	10.45	10.82	10.86	11.25	11.64	12.02	12.58	13.15	13.68	14.18	15.15	16.02	16.82	17.52	18.15	18.69							
2 13/16	2.813	8.357	8.520	8.980	9.071	9.431	9.764	9.874	10.31	10.73	11.11	11.15	11.56	11.96	12.35	12.94	13.53	14.08	14.60	15.61	16.52	17.37	18.11	18.78	19.36							
2 7/8	2.875	8.564	8.732	9.205	9.299	9.670	10.01	10.13	10.57	11.01	11.40	11.44	11.86	12.28	12.68	13.29	13.90	14.47	15.02	16.07	17.02	17.90	18.69	19.40	20.03							
2 15/16	2.938	8.775	8.947	9.434	9.530	9.912	10.26	10.38	10.84	11.29	11.69	11.74	12.17	12.60	13.02	13.65	14.28	14.87	15.44	16.53	17.53	18.45	19.28	20.04	20.70							
3	3.000	8.982	9.159	9.659	9.758	10.15	10.51	10.63	11.11	11.57	11.98	12.03	12.48	12.92	13.35	14.00	14.65	15.26	15.85	16.99	18.02	18.99	19.86	20.66	21.36							
3 1/16	3.063	9.193	9.374	9.888	9.989	10.39	10.77	10.89	11.38	11.86	12.28	12.33	12.79	13.24	13.69	14.36	15.03	15.66	16.27	17.45	18.53	19.54	20.45	21.29	22.03							

WEIGHT TABLE—SEAMLESS STEEL TUBING

3-1/8" to 14-3/8" Dia. — Wall Thickness—B.W.G. Fraction or Decimal — 5/16" to 2"

Fraction	Decimal Outside Diameter	5/16	.320	0	11/32	.360	3/8	00	.400	.420	7/16	.440	.460	.480	1/2
		.313	.320	.340	.344	.360	.375	.380	.400	.420	.438	.440	.460	.480	.500
3 1/8	3.125	9.400	9.586	10.11	10.22	10.63	11.01	11.14	11.64	12.13	12.57	12.62	13.09	13.56	14.02
3 3/16	3.188	9.611	9.802	10.34	10.45	10.87	11.27	11.40	11.91	12.42	12.86	12.91	13.40	13.88	14.35
3 1/4	3.250	9.818	10.01	10.57	10.68	11.11	11.51	11.65	12.18	12.69	13.15	13.20	13.71	14.20	14.69
3 5/16	3.313	10.03	10.23	10.80	10.91	11.35	11.77	11.90	12.44	12.98	13.45	13.50	14.02	14.52	15.02
3 3/8	3.375	10.24	10.44	11.02	11.14	11.59	12.02	12.15	12.71	13.25	13.74	13.79	14.32	14.84	15.35
3 7/16	3.438	10.45	10.66	11.25	11.37	11.83	12.27	12.41	12.98	13.54	14.03	14.09	14.63	15.16	15.69
3 1/2	3.500	10.65	10.87	11.47	11.59	12.07	12.52	12.66	13.24	13.82	14.32	14.38	14.93	15.48	16.02
3 9/16	3.563	10.86	11.08	11.70	11.83	12.31	12.77	12.92	13.51	14.10	14.62	14.68	15.24	15.80	16.36
3 5/8	3.625	11.07	11.30	11.93	12.05	12.55	13.02	13.17	13.78	14.38	14.91	14.97	15.55	16.12	16.69
3 11/16	3.688	11.28	11.51	12.16	12.29	12.80	13.27	13.43	14.05	14.66	15.20	15.26	15.86	16.45	17.02
3 3/4	3.750	11.49	11.72	12.38	12.51	13.03	13.52	13.68	14.31	14.94	15.49	15.55	16.16	16.76	17.36
3 13/16	3.813	11.70	11.94	12.61	12.74	13.28	13.77	13.93	14.58	15.22	15.79	15.85	16.47	17.09	17.69
3 7/8	3.875	11.91	12.15	12.84	12.97	13.51	14.02	14.18	14.85	15.50	16.08	16.14	16.78	17.40	18.02
3 15/16	3.938	12.12	12.36	13.07	13.20	13.76	14.27	14.44	15.11	15.78	16.37	16.44	17.09	17.73	18.36
4	4.000	12.33	12.58	13.29	13.43	14.00	14.52	14.69	15.38	16.06	16.66	16.73	17.39	18.04	18.69
4 1/8	4.125	12.74	13.00	13.74	13.89	14.48	15.02	15.20	15.91	16.62	17.25	17.32	18.01	18.69	19.36
4 1/4	4.250	13.16	13.43	14.20	14.35	14.96	15.52	15.71	16.45	17.18	17.83	17.90	18.62	19.33	20.03
4 3/8	4.375	13.58	13.86	14.65	14.81	15.44	16.02	16.21	16.98	17.74	18.42	18.49	19.23	19.97	20.69
4 1/2	4.500	14.00	14.29	15.11	15.27	15.92	16.52	16.72	17.52	18.30	19.00	19.08	19.85	20.61	21.36
4 5/8	4.625	14.41	14.71	15.56	15.73	16.40	17.02	17.23	18.05	18.86	19.59	19.67	20.46	21.25	22.03
4 3/4	4.750	14.83	15.14	16.01	16.19	16.88	17.52	17.74	18.58	19.42	20.17	20.25	21.08	21.89	22.70
4 7/8	4.875	15.25	15.57	16.47	16.65	17.36	18.02	18.24	19.12	19.98	20.76	20.84	21.69	22.53	23.36
5	5.000	15.67	15.99	16.92	17.11	17.84	18.52	18.75	19.65	20.54	21.34	21.43	22.30	23.17	24.03
5 1/8	5.125	16.09	16.42	17.38	17.57	18.32	19.02	19.26	20.19	21.10	21.93	22.02	22.92	23.81	24.70
5 1/4	5.250	16.50	16.85	17.83	18.02	18.80	19.52	19.76	20.72	21.67	22.51	22.60	23.53	24.45	25.37
5 3/8	5.375	16.92	17.28	18.28	18.48	19.28	20.03	20.27	21.25	22.23	23.09	23.19	24.15	25.09	26.03
5 1/2	5.500	17.34	17.70	18.74	18.94	19.76	20.53	20.78	21.79	22.79	23.68	23.78	24.76	25.73	26.70
5 5/8	5.625	17.76	18.13	19.19	19.40	20.24	21.03	21.29	22.32	23.35	24.26	24.37	25.37	26.38	27.37
5 3/4	5.750	18.18	18.56	19.64	19.86	20.72	21.53	21.79	22.86	23.91	24.85	24.95	25.99	27.02	28.04
5 7/8	5.875	18.59	18.98	20.10	20.32	21.20	22.03	22.30	23.39	24.47	25.43	25.54	26.60	27.66	28.70
6	6.000	19.01	19.41	20.55	20.78	21.68	22.53	22.81	23.92	25.03	26.02	26.13	27.22	28.30	29.37
6 1/8	6.125	19.43	19.84	21.01	21.24	22.17	23.03	23.32	24.46	25.59	26.60	26.71	27.83	28.94	30.04
6 1/4	6.250	19.85	20.27	21.46	21.70	22.65	23.53	23.82	24.99	26.15	27.19	27.30	28.45	29.58	30.71
6 3/8	6.375	20.26	20.69	21.91	22.16	23.13	24.03	24.33	25.53	26.71	27.77	27.89	29.06	30.22	31.37
6 1/2	6.500	20.68	21.12	22.37	22.62	23.61	24.53	24.84	26.06	27.27	28.36	28.48	29.67	30.86	32.04
6 5/8	6.625	21.10	21.55	22.82	23.08	24.09	25.03	25.34	26.59	27.83	28.94	29.06	30.29	31.50	32.71

Fraction	Decimal Outside Diameter	17/32	9/16	19/32	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	2
		.531	.563	.594	.625	.688	.750	.813	.875	.938	1.000	1.125	1.250	1.375	1.500	1.625	1.750	2.000
3 1/8	3.125	14.71	15.40	16.06	16.69	17.91	19.02	20.07	21.03	21.91	22.70	....	....	....	....	....	....	....
3 3/16	3.188	15.07	15.78	16.46	17.11	18.37	19.53	20.62	21.61	22.54	23.37	....	....	....	....	....	....	....
3 1/4	3.250	15.42	16.16	16.85	17.52	18.83	20.03	21.16	22.19	23.16	24.03	....	....	....	....	....	....	....
3 5/16	3.313	15.78	16.54	17.25	17.94	19.29	20.53	21.71	22.78	23.79	24.70	....	....	....	....	....	....	....
3 3/8	3.375	16.13	16.91	17.64	18.36	19.74	21.03	22.25	23.36	24.41	25.37	....	....	....	....	....	....	....
3 7/16	3.438	16.49	17.29	18.04	18.78	20.21	21.53	22.79	23.95	25.04	26.04	....	....	....	....	....	....	....
3 1/2	3.500	16.84	17.66	18.44	19.19	20.66	22.03	23.33	24.53	25.67	26.70	....	....	....	....	....	....	....
3 9/16	3.563	17.19	18.04	18.84	19.61	21.13	22.53	23.88	25.12	26.30	27.37	29.29	....	....	....	....	....	....
3 5/8	3.625	17.55	18.41	19.23	20.03	21.58	23.03	24.42	25.70	26.92	28.04	30.04	....	....	....	....	....	....
3 11/16	3.688	17.90	18.79	19.63	20.45	22.04	23.53	24.96	26.29	27.55	28.71	30.79	....	....	....	....	....	....
3 3/4	3.750	18.26	19.16	20.02	20.86	22.50	24.03	25.50	26.87	28.17	29.37	31.54	....	....	....	....	....	....
3 13/16	3.813	18.61	19.54	20.42	21.28	22.96	24.53	26.05	27.46	28.80	30.04	32.30	....	....	....	....	....	....
3 7/8	3.875	18.96	19.91	20.81	21.69	23.42	25.03	26.59	28.04	29.42	30.71	33.04	....	....	....	....	....	....
3 15/16	3.938	19.32	20.29	21.21	22.11	23.88	25.54	27.13	28.62	30.05	31.38	33.80	....	....	....	....	....	....
4	4.000	19.67	20.67	21.61	22.53	24.34	26.03	27.67	29.20	30.67	32.04	34.54	....	....	....	....	....	....
4 1/8	4.125	20.38	21.42	22.40	23.36	25.25	27.03	28.76	30.37	31.93	33.38	36.05	....	....	....	....	....	....
4 1/4	4.250	21.09	22.17	23.19	24.20	26.17	28.04	29.84	31.54	33.18	34.71	37.55	....	....	....	....	....	....
4 3/8	4.375	21.80	22.92	23.99	25.03	27.09	29.04	30.93	32.71	34.43	36.05	39.05	....	....	....	....	....	....
4 1/2	4.500	22.51	23.67	24.78	25.87	28.01	30.04	32.01	33.88	35.68	37.38	40.55	....	....	....	....	....	....
4 5/8	4.625	23.22	24.42	25.57	26.70	28.93	31.04	33.10	35.04	36.94	38.72	42.05	45.06	47.73	....	....	....	....
4 3/4	4.750	23.93	25.18	26.37	27.53	29.85	32.04	34.18	36.21	38.19	40.05	43.55	46.73	49.56	....	....	....	....
4 7/8	4.875	24.64	25.93	27.16	28.37	30.77	33.04	35.27	37.38	39.44	41.39	45.06	48.39	51.40	....	....	....	....
5	5.000	25.34	26.68	27.95	29.20	31.68	34.04	36.36	38.55	40.69	42.72	46.56	50.06	53.23	....	....	....	....
5 1/8	5.125	26.05	27.43	28.74	30.04	32.60	35.04	37.44	39.72	41.94	44.06	48.06	51.73	55.07	....	....	....	....
5 1/4	5.250	26.76	28.18	29.54	30.87	33.52	36.05	38.53	40.88	43.20	45.39	49.56	53.40	56.90	....	....	....	....
5 3/8	5.375	27.47	28.93	30.33	31.71	34.44	37.05	39.61	42.05	44.45	46.73	51.06	55.07	58.74	....	....	....	....
5 1/2	5.500	28.18	29.69	31.12	32.54	35.36	38.05	40.70	43.22	45.70	48.06	52.57	56.74	60.58	....	....	....	....
5 5/8	5.625	28.89	30.44	31.92	33.38	36.28	39.05	41.78	44.39	46.95	49.40	54.07	58.41	62.41	....	....	....	....
5 3/4	5.750	29.60	31.19	32.71	34.21	37.19	40.05	42.87	45.56	48.21	50.73	55.57	60.08	64.25	....	....	....	....
5 7/8	5.875	30.31	31.94	33.50	35.04	38.11	41.05	43.95	46.73	49.46	52.07	57.07	61.74	66.08	....	....	....	....
6	6.000	31.02	32.69	34.30	35.88	39.03	42.05	45.04	47.89	50.71	53.40	58.57	63.41	67.92	....	....	....	....
6 1/8	6.125	31.72	33.44	35.09	36.71	39.95	43.05	46.12	49.06	51.96	54.74	60.08	65.08	69.75	....	....	....	....
6 1/4	6.250	32.43	34.20	35.88	37.55	40.87	44.06	47.21	50.23	53.21	56.07	61.58	66.75	71.59	....	....	....	....
6 3/8	6.375	33.14	34.95	36.67	38.38	41.79	45.06	48.29	51.40	54.47	57.41	63.08	68.42	73.43	....	....	....	....
6 1/2	6.500	33.85	35.70	37.47	39.22	42.71	46.06	49.38	52.57	55.72	58.74	64.58	70.09	75.26	....	....	....	....
6 5/8	6.625	34.56	36.45	38.26	40.05	43.62	47.06	50.46	53.73	56.97	60.08	66.08	71.76	77.10	....	....	....	....

6¾	6.750	21.52	21.98	23.28	23.54	24.57	25.53	25.85	27.13	28.39	29.53	29.65	30.90	32.14	33.38	35.27	37.20	39.05	40.88	44.54	48.06	51.55	54.90	58.22	61.41	67.58	73.43	78.93	....	....	....	....
6⅞	6.875	21.94	22.40	23.73	23.99	25.05	26.03	26.36	27.66	28.95	30.11	30.24	31.52	32.78	34.04	35.98	37.95	39.85	41.72	45.46	49.06	52.64	56.07	59.48	62.75	69.09	75.09	80.77	....	....	....	....
7	7.000	22.35	22.83	24.18	24.45	25.53	26.53	26.87	28.20	29.52	30.70	30.83	32.13	33.42	34.71	36.69	38.70	40.64	42.55	46.38	50.06	53.72	57.24	60.73	64.08	70.59	76.76	82.60	....	....	....	....
7⅛	7.125	22.77	23.26	24.64	24.91	26.01	27.03	27.37	28.73	30.08	31.28	31.41	32.74	34.06	35.38	37.40	39.46	41.43	43.39	47.30	51.06	54.81	58.41	61.98	65.42	72.09	78.43	84.44	....	....	....	....
7¼	7.250	23.19	23.68	25.09	25.37	26.49	27.53	27.88	29.26	30.64	31.87	32.00	33.36	34.71	36.05	38.10	40.21	42.23	44.22	48.22	52.07	55.89	59.57	63.23	66.75	73.59	80.10	86.27	....	....	....	....
7⅜	7.375	23.61	24.11	25.55	25.83	26.97	28.04	28.39	29.80	31.20	32.45	32.59	33.97	35.35	36.71	38.81	40.96	43.02	45.06	49.14	53.07	56.98	60.74	64.48	68.09	75.09	81.77	88.11	....	....	....	....
7½	7.500	24.02	24.54	26.00	26.29	27.45	28.54	28.90	30.33	31.76	33.03	33.18	34.59	35.99	37.38	39.52	41.71	43.81	45.89	50.05	54.07	58.06	61.91	65.74	69.42	76.60	83.44	89.95	96.12	102.0	....	....
7⅝	7.625	24.44	24.97	26.45	26.75	27.93	29.04	29.40	30.87	32.30	33.62	33.76	35.20	36.63	38.05	40.23	42.46	44.60	46.73	50.97	55.07	59.15	63.08	66.99	70.76	78.10	85.11	91.78	98.12	104.1	....	....
7¾	7.750	24.86	25.39	26.91	27.21	28.41	29.54	29.91	31.40	32.88	34.20	34.35	35.81	37.27	38.72	40.94	43.21	45.40	47.56	51.89	56.07	60.23	64.25	68.24	72.09	79.60	86.78	93.62	100.1	106.3	....	....
8	8.000	25.70	26.25	27.81	28.13	29.37	30.54	30.93	32.47	34.00	35.37	35.53	37.04	38.55	40.05	42.36	44.72	46.98	49.23	53.73	58.07	62.40	66.58	70.75	74.76	82.60	90.11	97.29	104.1	110.6	....	....
8¼	8.250	26.53	27.10	28.72	29.05	30.34	31.54	31.94	33.54	35.12	36.54	36.70	38.27	39.83	41.39	43.78	46.22	48.57	50.90	55.56	60.08	64.57	68.92	73.25	77.43	85.61	93.45	101.0	108.1	115.0	....	....
8½	8.500	27.37	27.96	29.63	29.96	31.30	32.54	32.95	34.60	36.24	37.71	37.88	39.50	41.11	42.72	45.19	47.72	50.16	52.57	57.40	62.08	66.74	71.26	75.75	80.10	88.61	96.79	104.6	112.1	119.3	....	....
8⅝	8.625	27.79	28.38	30.08	30.42	31.78	33.04	33.46	35.14	36.80	38.30	38.46	40.11	41.75	43.39	45.90	48.48	50.95	53.40	58.32	63.08	67.83	72.42	77.01	81.44	90.11	98.46	106.5	114.1	121.5	....	....
8¾	8.750	28.20	28.81	30.54	30.88	32.26	33.54	33.97	35.67	37.37	38.88	39.05	40.73	42.40	44.06	46.61	49.23	51.74	54.23	59.24	64.08	68.92	73.59	78.26	82.77	91.61	100.1	108.3	116.1	123.7	....	....
9	9.000	29.04	29.66	31.45	31.80	33.22	34.54	34.98	36.74	38.49	40.05	40.23	41.96	43.68	45.39	48.03	50.73	53.33	55.90	61.08	66.08	71.09	75.93	80.76	85.44	94.62	103.5	112.0	120.2	128.0	....	....
9¼	9.250	29.87	30.52	32.35	32.72	34.18	35.54	36.00	37.81	39.61	41.22	41.40	43.18	44.96	46.73	49.45	52.23	54.91	57.57	62.91	68.09	73.26	78.26	83.27	88.11	97.62	106.8	115.6	124.2	132.3	....	....
9½	9.500	30.71	31.37	33.26	33.64	35.14	36.55	37.01	38.88	40.73	42.39	42.57	44.41	46.24	48.06	50.86	53.74	56.50	59.24	64.75	70.09	75.43	80.60	85.77	90.78	100.6	110.1	119.3	128.2	136.7	....	....
9⅝	9.625	31.13	31.80	33.72	34.10	35.62	37.05	37.52	39.41	41.29	42.98	43.16	45.03	46.88	48.73	51.57	54.49	57.29	60.08	65.67	71.09	76.51	81.77	87.02	92.12	102.1	111.8	121.2	130.2	138.8	....	....
9¾	9.750	31.55	32.23	34.17	34.56	36.10	37.55	38.03	39.94	41.85	43.56	43.75	45.64	47.52	49.40	52.28	55.24	58.08	60.91	66.59	72.09	77.60	82.94	88.28	93.45	103.6	113.5	123.0	132.2	141.0	....	....
10	10.000	32.38	33.08	35.08	35.48	37.06	38.55	39.04	41.01	42.97	44.73	44.92	46.87	48.80	50.73	53.70	56.74	59.67	62.58	68.42	74.09	79.77	85.27	90.78	96.12	106.6	116.8	126.7	136.2	145.3	....	....
10¼	10.250	33.22	33.94	35.99	36.39	38.03	39.55	40.06	42.08	44.09	45.90	46.10	48.10	50.08	52.07	55.12	58.25	61.26	64.25	70.26	76.10	81.94	87.61	93.29	98.79	109.6	120.2	130.3	140.2	149.7	....	....
10½	10.500	34.05	34.79	36.89	37.31	38.99	40.55	41.07	43.15	45.21	47.07	47.27	49.32	51.37	53.40	56.53	59.75	62.84	65.92	72.10	78.10	84.11	89.95	95.79	101.5	112.6	123.5	134.0	144.2	154.0	....	....
10¾	10.750	34.89	35.65	37.80	38.23	39.95	41.55	42.09	44.22	46.34	48.24	48.45	50.55	52.65	54.74	57.95	61.25	64.43	67.58	73.93	80.10	86.28	92.28	98.30	104.1	115.6	126.8	137.7	148.2	158.4	....	....
11	11.000	35.72	36.50	38.71	39.15	40.91	42.55	43.10	45.28	47.46	49.41	49.62	51.78	53.93	56.07	59.37	62.76	66.01	69.25	75.77	82.10	88.45	94.62	100.8	106.8	118.6	130.2	141.3	152.2	162.7	172.9	192.2
11¼	11.250	36.56	37.35	39.62	40.07	41.87	43.55	44.11	46.35	48.58	50.58	50.80	53.01	55.21	57.41	60.79	64.26	67.60	70.92	77.61	84.11	90.62	96.95	103.3	109.5	121.7	133.5	145.0	156.2	167.0	177.6	197.6
11½	11.500	37.40	38.21	40.52	40.99	42.83	44.56	45.13	47.42	49.70	51.75	51.97	54.24	56.49	58.74	62.21	65.76	69.19	72.59	79.44	86.11	92.79	99.29	105.8	112.1	124.7	136.8	148.7	160.2	171.4	182.2	202.9
11¾	11.750	38.23	39.06	41.43	41.90	43.79	45.56	46.14	48.49	50.82	52.92	53.15	55.47	57.77	60.08	63.63	67.27	70.77	74.26	81.28	88.11	94.96	101.6	108.3	114.8	127.7	140.2	152.4	164.2	175.7	186.9	208.3
12	12.000	39.07	39.92	42.44	42.82	44.75	46.56	47.16	49.56	51.94	54.09	54.32	56.69	59.06	61.41	65.04	68.77	72.36	75.93	83.12	90.11	97.13	104.0	110.8	117.5	130.7	143.5	156.0	168.2	180.1	191.6	213.6
12¼	12.250	39.90	40.77	43.25	43.74	45.71	47.56	48.17	50.62	53.06	55.25	55.50	57.92	60.34	62.75	66.46	70.27	73.94	77.60	84.96	92.12	99.31	106.3	113.3	120.2	133.7	146.9	159.7	172.2	184.4	196.2	218.9
12½	12.500	40.74	41.63	44.16	44.66	46.68	48.56	49.19	51.69	54.19	56.42	56.67	59.15	61.62	64.08	67.88	71.78	75.53	79.27	86.79	94.12	101.5	108.6	115.8	122.8	136.7	150.2	163.4	176.2	188.7	200.9	224.3
12¾	12.750	41.57	42.48	45.06	45.58	47.64	49.56	50.20	52.76	55.31	57.59	57.85	60.38	62.90	65.42	69.29	73.28	77.12	80.93	88.63	96.12	103.6	111.0	118.3	125.5	139.7	153.5	167.0	180.2	193.1	205.6	229.6
13	13.000	42.41	43.34	45.97	46.50	48.60	50.56	51.22	53.83	56.43	58.76	59.02	61.61	64.18	66.75	70.71	74.78	78.70	82.60	90.47	98.12	105.8	113.3	120.8	128.2	142.7	156.9	170.7	184.2	197.4	210.3	235.0
13¼	13.250	43.25	44.19	46.88	47.42	49.56	51.56	52.23	54.90	57.55	59.93	60.20	62.83	65.46	68.09	72.13	76.28	80.29	84.27	92.30	100.1	108.0	115.6	123.3	130.8	145.7	160.2	174.4	188.2	201.8	214.9	240.3
13½	13.500	44.08	45.04	47.79	48.33	50.52	52.57	53.25	55.96	58.67	61.10	61.37	64.06	66.75	69.42	73.55	77.79	81.87	85.94	94.14	102.1	110.2	118.0	125.8	133.5	148.7	163.5	178.1	192.2	206.1	219.6	245.6
13¾	13.750	44.92	45.90	48.69	49.25	51.48	53.57	54.26	57.03	59.79	62.27	62.55	65.29	68.03	70.76	74.97	79.29	83.46	87.61	95.90	104.1	112.3	120.3	128.3	136.2	151.7	166.9	181.7	196.2	210.4	224.3	251.0
14	14.000	45.75	46.75	49.60	50.17	52.44	54.57	55.28	58.10	60.91	63.44	63.72	66.52	69.31	72.09	76.38	80.79	85.05	89.28	97.81	106.1	114.5	122.7	130.9	138.8	154.7	170.2	185.4	200.3	214.8	229.0	256.3
14¼	14.250	46.59	47.61	50.51	51.09	53.40	55.57	56.29	59.17	62.04	64.61	64.90	67.75	70.59	73.43	77.80	82.30	86.63	90.95	99.65	108.1	116.7	125.0	133.4	141.5	157.7	173.6	189.1	204.3	219.1	233.6	261.7
14⅜	14.275	47.01	48.03	50.96	51.55	53.88	56.07	56.80	59.70	62.60	65.20	65.48	68.36	71.23	74.09	78.51	83.05	87.43	91.78	100.6	109.1	117.8	126.2	134.6	142.8	159.2	175.2	190.9	206.3	221.3	236.0	264.3

PROPERTIES OF SEAMLESS TUBING

SECTIONAL AREA OF WALL IN SQUARE INCHES

Outside Diameter Inches	THICKNESS IN GAGES							
	24 B.W.G.	23 B.W.G.	22 B.W.G.	21 B.W.G.	20 B.W.G.	19 B.W.G.	18 B.W.G.	17 B.W.G.
1/4	.0157	.0176	.0195	.0219	.0236	.0274	.0309	0349
5/16	.0200	.0225	.0250	.0281	.0305	.0356	.0405	.0463
3/8	.0243	.0274	.0305	.0344	.0373	.0439	.0501	.0577
7/16	.0287	.0323	.0360	.0407	.0442	.0521	.0598	.0691
1/2	.0330	.0373	.0415	.0470	.0511	.0604	.0694	.0805
9/16	.0373	.0422	.0470	.0533	.0580	.0686	.0790	.0919
5/8	.0416	.0471	.0525	.0596	.0648	.0769	.0886	.1033
11/16	.0459	.0520	.0580	.0658	.0717	.0851	.0982	.1147
3/4	.0503	.0569	.0635	.0721	.0786	.0934	.1079	.1260
13/16	.0546	.0618	.0690	.0784	.0854	.1016	.1175	.1374
7/8	.0589	.0667	.0745	.0847	.0923	.1099	.1271	.1488
15/16	.0632	.0716	.0800	.0910	.0992	.1181	.1367	.1602
1	.0675	.0765	.0855	.0973	.1061	.1264	.1463	.1716
1 1/16	.0719	.0814	.0909	.1035	.1129	.1346	.1560	.1830
1 1/8	.0762	.0863	.0964	.1098	.1198	.1428	.1656	.1944
1 3/16	.0805	.0913	.1019	.1161	.1267	.1511	.1752	.2058
1 1/4	.0848	.0962	.1074	.1224	.1335	.1593	.1848	.2171
1 5/16	.0891	.1011	.1129	.1287	.1404	.1676	.1945	.2285
1 3/8	.0935	.1060	.1184	.1350	.1473	.1758	.2041	.2399
1 7/16	.0978	.1109	.1239	.1412	.1542	.1841	.2137	.2513
1 1/2	.1021	.1158	.1294	.1475	.1610	.1923	.2233	.2627
1 5/8	.1107	.1256	.1404	.1601	.1748	.2088	.2426	.2855
1 3/4	.1194	.1354	.1514	.1727	.1885	.2253	.2618	.3083
1 7/8	.1280	.1452	.1624	.1852	.2023	.2418	.2810	.3310
2	.1367	.1551	.1734	.1978	.2160	.2583	.3003	.3538
2 1/8	....	....	....	....	....	....	.3195	.3766
2 1/4	....	....	....	....	....	....	.3388	.3994
2 3/8	....	....	....	....	....	....	.3580	.4221
2 1/2	....	....	....	....	....	....	.3773	.4449
2 5/8	....	....	....	....	....	....	.3965	.4677
2 3/4	....	....	....	....	....	....	.4157	.4905
2 7/8	....	....	....	....	....	....	.4350	.5132
3	....	....	....	....	....	....	.4542	.5360
3 1/8	....	....	....	....	....	....	.4735	.5588
3 1/4	....	....	....	....	....	....	.4927	.5816

SECTIONAL AREA OF WALL IN SQUARE INCHES

(Continued)

Outside Diameter Inches	THICKNESS IN GAGES							
	16 B.W.G.	15 B.W.G.	14 B.W.G.	13 B.W.G.	12 B.W.G.	11 B.W.G.	10 B.W.G.	9 B.W.G.
1/4	.0377	.0402	.0435	.0462	....	....	....	....
5/16	.0505	.0544	.0598	.0649	.0696	.0725	....	....
3/8	.0633	.0685	.0761	.0835	.0910	.0961	.1014	....
7/16	.0760	.0826	.0924	.1022	.1124	.1196	.1277	....
1/2	.0888	.0968	.1087	.1208	.1338	.1432	.1540	.1636
9/16	.1015	.1109	.1250	.1395	.1552	.1668	.1803	.1927
5/8	.1143	.1250	.1413	.1581	.1766	.1903	.2066	.2217
11/16	.1271	.1392	.1576	.1768	.1980	.2139	.2330	.2508
3/4	.1398	.1533	.1739	.1954	.2195	.2375	.2593	.2799
13/16	.1526	.1674	.1902	.2141	.2409	.2610	.2856	.3089
7/8	.1654	.1816	.2065	.2327	.2623	.2846	.3119	.3380
15/16	.1781	.1957	.2228	.2514	.2837	.3081	.3382	.3670
1	.1909	.2099	.2391	.2700	.3051	.3317	.3645	.3961
1 1/16	.2036	.2240	.2554	.2887	.3265	.3553	.3908	.4252
1 1/8	.2164	.2381	.2717	.3074	.3479	.3788	.4171	.4542
1 3/16	.2292	.2523	.2880	.3260	.3693	.4024	.4434	.4833
1 1/4	.2419	.2664	.3042	.3447	.3907	.4260	.4698	.5123
1 5/16	.2547	.2805	.3205	.3633	.4121	.4495	4961	.5414
1 3/8	.2675	.2947	.3368	.3820	.4335	.4731	.5224	.5705
1 7/16	.2802	.3088	.3531	.4006	.4549	.4966	.5487	.5995
1 1/2	.2930	.3230	.3694	.4193	.4763	.5202	.5750	.6286
1 5/8	.3185	.3512	.4020	.4566	.5191	.5673	.6276	.6867
1 3/4	.3440	.3795	.4346	.4939	.5619	.6144	.6802	.7448
1 7/8	.3696	.4078	.4672	.5312	.6047	.6616	.7329	.8029
2	.3951	.4361	.4998	.5685	.6475	.7087	.7855	.8610
2 1/4	.4461	.4926	.5650	.6431	.7331	.8029	.8907	.9773
2 3/8	.4717	.5209	.5976	.6804	.7759	.8501	.9434	.0354
2 1/2	.4972	.5492	.6302	.7177	.8187	.8972	.9960	1.0935
2 5/8	.5227	.5774	.6628	.7550	.8615	.9443	1.0486	1.1516
2 3/4	.5482	.6057	.6954	.7923	.9043	.9914	1.1012	1.2098
2 7/8	.5738	.6340	.7280	.8296	.9471	1.0386	1.1538	1.2679
3	.5993	.6622	.7606	.8670	.9899	1.0857	1.2065	1.3260
3 1/4	.6503	.7188	.8258	.9416	1.0755	1.1799	1.3117	1.4422
3 3/8	.6759	.7471	.8583	.9789	1.1183	1.2271	1.3643	1.5004
3 1/2	.7014	.7753	.8909	1.0162	1.1611	1.2742	1.4169	1.5585
3 5/8	.7269	.8036	.9235	1.0535	1.2039	1.3213	1.4696	1.6166
3 3/4	.7524	.8319	.9561	1.0908	1.2468	1.3684	1.5222	1.6747
3 7/8	.7780	.8602	.9887	1.1281	1.2896	1.4156	1.5748	1.7328
4	.8035	.8884	1.0213	1.1654	1.3324	1.4627	1.6274	1.7910
4 1/4	.8545	.9450	1.0865	1.2400	1.4180	1.5569	1.7327	1.9072
4 1/2	.9056	1.0015	1.1517	1.3146	1.5036	1.6512	1.8379	2.0234
4 3/4	.9566	1.0581	1.2169	1.3892	1.5892	1.7454	1.9432	2.1397
5	1.0077	1.1146	1.2821	1.4639	1.6748	1.8397	2.0484	2.2559
5 1/4	1.0587	1.1712	1.3473	1.5385	1.7604	1.9339	2.1537	2.3722
5 1/2	1.1098	1.2277	1.4124	1.6131	1.8460	2.0282	2.2589	2.4884
5 3/4	....	....	....	....	....	....	2.3641	2.6046
6	....	....	....	....	....	....	2.4694	2.7209
6 1/4	....	....	....	....	....	....	2.5746	2.8371
6 1/2	....	....	....	....	....	....	2.6799	2.9533
6 3/4	....	....	....	....	....	....	2.7851	3.0696
7	....	....	....	....	....	....	2.8904	3.1858
7 1/4	....	....	....	....	....	....	2.9956	3.3021
7 1/2	....	....	....	....	....	....	3.1008	3.4183
7 3/4	....	....	....	....	....	....	3.2061	3.5345
8	....	....	....	....	....	....	3.3113	3.6508
8 1/4	....	....	....	....	....	....	3.4166	3.7670
8 1/2	....	....	....	....	....	....	3.5218	3.8833
8 3/4	....	....	....	....	....	....	3.6271	3.9995
9	....	....	....	....	....	....	3.7323	4.1157

SECTIONAL AREA OF WALL IN SQUARE INCHES

(Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	5/32″	8 B.W.G.	7 B.W.G.	3/16″	6 B.W.G.	7/32″	5 B.W.G.	4 B.W.G.
5/8	.2300	.2384	.2516	.2577	....	....	....	....
11/16″	.2607	.2708	.2869	.2945	.3089	.3221	.3231	.3360
3/4	.2914	.3032	.3223	.3313	.3488	.3650	.3663	.3828
13/16″	.3221	.3356	.3576	.3681	.3887	.4080	.4095	.4295
7/8	.3528	.3680	.3930	.4049	.4285	.4509	.4527	.4762
15/16″	.3834	.4004	.4283	.4417	.4684	.4939	.4959	.5230
1	.4141	.4328	.4636	.4786	.5082	.5368	.5390	.5697
1 1/16	.4448	.4652	.4990	.5154	.5481	.5798	.5822	.6164
1 1/8	.4755	.4976	.5343	.5522	.5879	.6227	.6254	.6632
1 3/16	.5062	.5300	.5697	.5890	.6278	.6657	.6686	.7099
1 1/4	.5368	.5624	.6050	.6258	.6677	.7086	.7118	.7566
1 5/16	.5675	.5948	.6404	.6626	.7075	.7516	.7550	.8034
1 3/8	.5982	.6272	.6757	.6994	.7474	.7946	.7982	.8501
1 7/16	.6289	.6596	.7111	.7363	.7872	.8375	.8414	.8968
1 1/2	.6596	.6920	.7464	.7731	.8271	.8805	.8846	.9435
1 5/8	.7209	.7568	.8171	.8467	.9068	.9664	.9710	1.0370
1 3/4	.7823	.8216	.8878	.9203	.9865	1.0523	1.0574	1.1305
1 7/8	.8436	.8864	.9585	.9940	1.0663	1.1382	1.1438	1.2239
2	.9050	.9511	1.0291	1.0676	1.1460	1.2241	1.2302	1.3174
2 1/8	.9664	1.0159	1.0998	1.1412	1.2257	1.3100	1.3166	1.4109
2 1/4	1.0277	1.0807	1.1705	1.2149	1.3054	1.3959	1.4030	1.5043
2 3/8	1.0891	1.1455	1.2412	1.2885	1.3851	1.4818	1.4894	1.5978
2 1/2	1.1504	1.2103	1.3119	1.3621	1.4648	1.5677	1.5758	1.6912
2 5/8	1.2118	1.2751	1.3826	1.4358	1.5446	1.6536	1.6622	1.7847
2 3/4	1.2732	1.3399	1.4533	1.5094	1.6243	1.7395	1.7486	1.8782
2 7/8	1.3345	1.4047	1.5239	1.5830	1.7040	1.8254	1.8350	1.9716
3	1.3959	1.4695	1.5946	1.6566	1.7837	1.9113	1.9213	2.0651
3 1/8	1.4572	1.5343	1.6653	1.7303	1.8634	1.9972	2.0077	2.1586
3 1/4	1.5186	1.5991	1.7360	1.8039	1.9432	2.0831	2.0941	2.2520
3 3/8	1.5800	1.6639	1.8067	1.8775	2.0229	2.1690	2.1805	2.3455
3 1/2	1.6413	1.7287	1.8774	1.9512	2.1026	2.2549	2.2669	2.4389
3 5/8	1.7027	1.7935	1.9481	2.0248	2.1823	2.3408	2.3533	2.5324
3 3/4	1.7640	1.8583	2.0187	2.0984	2.2620	2.4267	2.4397	2.6259
3 7/8	1.8254	1.9231	2.0894	2.1721	2.3417	2.5126	2.5261	2.7193
4	1.8867	1.9879	2.1601	2.2457	2.4215	2.5985	2.6125	2.8128
4 1/8	1.9481	2.0527	2.2308	2.3193	2.5012	2.6844	2.6989	2.9063
4 1/4	2.0095	2.1175	2.3015	2.3930	2.5809	2.7703	2.7853	2.9997
4 3/8	2.0708	2.1823	2.3722	2.4666	2.6606	2.8562	2.8717	3.0932
4 1/2	2.1322	2.2471	2.4429	2.5402	2.7403	2.9421	2.9581	3.1866
4 5/8	2.1935	2.3118	2.5135	2.6139	2.8201	3.0280	3.0445	3.2801
4 3/4	2.2549	2.3766	2.5842	2.6875	2.8998	3.1139	3.1309	3.3736
4 7/8	2.3163	2.4414	2.6549	2.7611	2.9795	3.1998	3.2173	3.4670
5	2.3776	2.5062	2.7256	2.8347	3.0592	3.2857	3.3036	3.5605
5 1/4	2.5003	2.6358	2.8670	2.9820	3.2186	3.4575	3.4764	3.7474
5 1/2	2.6231	2.7654	3.0083	3.1293	3.3781	3.6293	3.6492	3.9343
5 3/4	2.7458	2.8950	3.1497	3.2765	3.5375	3.8012	3.8220	4.1213
6	2.8685	3.0246	3.2911	3.4238	3.6969	3.9730	3.9948	4.3082
6 1/4	2.9912	3.1542	3.4325	3.5711	3.8564	4.1448	4.1676	4.4951
6 1/2	3.1139	3.2838	3.5738	3.7183	4.0158	4.3166	4.3404	4.6820
6 3/4	3.2367	3.4134	3.7152	3.8656	4.1753	4.4884	4.5132	4.8690
7	3.3594	3.5430	3.8566	4.0128	4.3347	4.6602	4.6860	5.0559
7 1/4	3.4821	3.6726	3.9979	4.1601	4.4941	4.8320	4.8587	5.2428
7 1/2	3.6048	3.8021	4.1393	4.3074	4.6536	5.0038	5.0315	5.4297
7 3/4	3.7275	3.9317	4.2807	4.4546	4.8130	5.1756	5.2043	5.6167
8	3.8502	4.0613	4.4221	4.6019	4.9724	5.3474	5.3771	5.8036
8 1/4	3.9730	4.1909	4.5634	4.7492	5.1319	5.5192	5.5499	5.9905
8 1/2	4.0957	4.3205	4.7048	4.8964	5.2913	5.6910	5.7227	6.1774
8 3/4	4.2184	4.4501	4.8462	5.0437	5.4507	5.8628	5.8955	6.3644
9	4.3411	4.5797	4.9875	5.1909	5.6102	6.0346	6.0683	6.5513
9 1/4	....	....	....	....	5.7697	6.2065	6.2411	6.7383
9 1/2	....	....	....	....	....	....	6.4139	6.9252
9 3/4	....	....	....	....	....	....	6.5867	7.1121
10	....	....	....	....	....	....	6.7595	7.2991
10 1/4	....	....	....	....	....	....	....	7.4860
10 1/2	....	....	....	....	....	....	....	7.6729

SECTIONAL AREA OF WALL IN SQUARE INCHES

(Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	1/4"	3 B.W.G.	9/32"	2 B.W.G.	1 B.W.G.	5/16"	0 B.W.G.	11/32"
11/16	.3436	....	.4141	.4157	.4241	....	....	....
3/4	.3926	.3995	.4693	.4715	.4830	.4295	....	....
13/16	.4417	.4503	.5246	.5272	.5419	.4908	.5046	.5062
7/8	.4908	.5012	.5798	.5830	.6008	.5522	.5714	.5737
15/16	.5399	.5520	.6350	.6388	.6597	.6135	.6382	.6412
1	.5890	.6029				.6749	.7049	.7086
1 1/16	.6381	.6537	.6902	.6945	.7186	.7363	.7717	.7761
1 1/8	.6872	.7046	.7455	.7503	.7775	.7976	.8384	.8436
1 3/16	.7363	.7554	.8007	.8061	.8364	.8590	.9052	.9111
1 1/4	.7853	.8063	.8559	.8618	.8953	.9203	.9720	.9786
1 5/16	.8344	.8572	.9111	.9176	.9542	.9817	1.0387	1.0461
1 3/8	.8835	.9080	.9664	.9734	1.0131	1.0431	1.1055	1.1136
1 7/16	.9326	.9589	1.0216	1.0291	1.0720	1.1044	1.1722	1.1811
1 1/2	.9817	1.0097	1.0768	1.0849	1.1309	1.1658	1.2390	1.2486
1 5/8	1.0799	1.1114	1.1873	1.1964	1.2487	1.2885	1.3725	1.3836
1 3/4	1.1780	1.2131	1.2977	1.3079	1.3665	1.4112	1.5060	1.5186
1 7/8	1.2762	1.3148	1.4081	1.4195	1.4844	1.5339	1.6395	1.6536
2	1.3744	1.4166	1.5186	1.5310	1.6022	1.6566	1.7731	1.7886
2 1/8	1.4726	1.5183	1.6290	1.6425	1.7200	1.7794	1.9066	1.9236
2 1/4	1.5707	1.6200	1.7395	1.7540	1.8378	1.9021	2.0401	2.0586
2 3/8	1.6689	1.7217	1.8499	1.8656	1.9556	2.0248	2.1736	2.1935
2 1/2	1.7671	1.8234	1.9604	1.9771	2.0734	2.1475	2.3071	2.3285
2 5/8	1.8653	1.9251	2.0708	2.0886	2.1912	2.2702	2.4407	2.4635
2 3/4	1.9634	2.0268	2.1813	2.2001	2.3000	2.3930	2.5742	2.5985
2 7/8	2.0616	2.1285	2.2917	2.3117	2.4268	2.5157	2.7077	2.7335
3	2.1598	2.2302	2.4022	2.4232	2.5446	2.6384	2.8412	2.8685
3 1/8	2.2580	2.3319	2.5126	2.5347	2.6625	2.7611	2.9747	3.0035
3 1/4	2.3561	2.4336	2.6231	2.6463	2.7803	2.8838	3.1082	3.1385
3 3/8	2.4543	2.5354	2.7335	2.7578	2.8981	3.0066	3.2418	3.2735
3 1/2	2.5525	2.6371	2.8440	2.8693	3.0159	3.1293	3.3753	3.4085
3 5/8	2.6507	2.7388	2.9544	2.9808	3.1337	3.2520	3.5088	3.5434
3 3/4	2.7488	2.8405	3.0648	3.0924	3.2515	3.3747	3.6423	3.6784
3 7/8	2.8470	2.9422	3.1753	3.2039	3.3693	3.4974	3.7758	3.8134
4	2.9452	3.0439	3.2857	3.3154	3.4871	3.6201	3.9093	3.9484
4 1/8	3.0434	3.1456	3.3962	3.4269	3.6049	3.7429	4.0429	4.0834
4 1/4	3.1415	3.2473	3.5066	3.5385	3.7227	3.8656	4.1764	4.2184
4 3/8	3.2397	3.3490	3.6171	3.6500	3.8405	3.9883	4.3099	4.3534
4 1/2	3.3379	3.4507	3.7275	3.7615	3.9584	4.1110	4.4434	4.4884
4 5/8	3.4361	3.5524	3.8380	3.8730	4.0762	4.2337	4.5769	4.6234
4 3/4	3.5342	3.6542	3.9484	3.9846	4.1940	4.3565	4.7105	4.7584
4 7/8	3.6324	3.7559	4.0589	4.0961	4.3118	4.4792	4.8440	4.8933
5	3.7306	3.8576	4.1693	4.2076	4.4296	4.6019	4.9775	5.0283
5 1/8	3.8288	3.9593	4.2798	4.3192	4.5474	4.7246	5.1110	5.1633
5 1/4	3.9269	4.0610	4.3902	4.4307	4.6652	4.8473	5.2445	5.2983
5 1/2	4.1233	4.2644	4.6111	4.6537	4.9008	5.0928	5.5116	5.5683
5 3/4	4.3196	4.4678	4.8320	4.8768	5.1365	5.3382	5.7786	5.8383
6	4.5160	4.6712	5.0529	5.0998	5.3721	5.5836	6.0456	6.1083
6 1/4	4.7123	4.8747	5.2738	5.3229	5.6077	5.8291	6.3127	6.3782
6 1/2	4.9087	5.0781	5.4947	5.5459	5.8433	6.0745	6.5797	6.6482
6 3/4	5.1050	5.2815	5.7156	5.7690	6.0789	6.3200	6.8467	6.9182
7	5.3014	5.4849	5.9365	5.9920	6.3146	6.5654	7.1138	7.1882
7 1/4	5.4977	5.6883	6.1573	6.2151	6.5502	6.8108	7.3808	7.4582
7 1/2	5.6941	5.8918	6.3782	6.4382	6.7858	7.0563	7.6478	7.7281
7 3/4	5.8904	6.0952	6.5991	6.6612	7.0214	7.3017	7.9149	7.9981
8	6.0868	6.2986	6.8200	6.8843	7.2570	7.5471	8.1819	8.2681
8 1/4	6.2831	6.5020	7.0409	7.1073	7.4926	7.7926	8.4489	8.5381
8 1/2	6.4795	6.7054	7.2618	7.3304	7.7283	8.0380	8.7160	8.8081
8 3/4	6.6758	6.9088	7.4827	7.5534	7.9639	8.2834	8.9830	9.0780
9	6.8722	7.1123	7.7036	7.7765	8.1995	8.5289	9.2501	9.3480
9 1/4	7.0686	7.3157	7.9246	7.9996	8.4352	8.7744	9.5172	9.6181
9 1/2	7.2649	7.5192	8.1455	8.2226	8.6708	9.0198	9.7842	9.8881
9 3/4	7.4613	7.7226	8.3663	8.4457	8.9064	9.2653	10.0512	10.1580
10	7.6577	7.9260	8.5872	8.6688	9.1421	9.5107	10.3183	10.4280
10 1/4	7.8540	8.1294	8.8081	8.8918	9.3777	9.7561	10.5853	10.6980
10 1/2	8.0504	8.3328	9.0290	9.1149	9.6133	10.0016	10.8523	10.9680
10 3/4	....	8.5363	9.2499	9.3379	9.8489	10.2470	11.1194	11.2380
11	....	8.7397	9.4708	9.5610	10.0845	10.4925	11.3864	11.5079
11 1/4	....	8.9431	9.6917	9.7840	10.3202	10.7379	11.6535	11.7779
11 1/2	....	9.1465	9.9126	10.0071	10.5558	10.9833	11.9205	12.0479
11 3/4	....	9.3499	10.1335	10.2301	10.7914	11.2288	12.1875	12.3179
12	....	9.5534	10.3544	10.4532	11.0270	11.4742	12.4546	12.5879

SECTIONAL AREA OF WALL IN SQUARE INCHES

(Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH						
	3/8"	00 B.W.G.	000 B.W.G.	7/16"	0000 B.W.G.	1/2"	9/16"
13/16	.5154	....	....	....	....	....	....
7/8	.5890	....	....	....	....	....	....
15/16	.6626	.6655	.6842	.6872	....	....	....
1	.7363	.7401	.7677	.7731	.7787	....	....
1 1/16	.8099	.8147	.8511	.8590	.8678	....	....
1 1/8	.8835	.8893	.9346	.9449	.9570	.9817	....
1 3/16	.9572	.9639	1.0180	1.0308	1.0461	1.0799	....
1 1/4	1.0308	1.0386	1.1015	1.1167	1.1353	1.1780	....
1 5/16	1.1044	1.1132	1.1849	1.2026	1.2244	1.2762	....
1 3/8	1.1780	1.1878	1.2684	1.2885	1.3136	1.3744	1.4358
1 7/16	1.2517	1.2624	1.3518	1.3744	1.4027	1.4726	1.5462
1 1/2	1.3253	1.3370	1.4353	1.4603	1.4918	1.5707	1.6566
1 5/8	1.4726	1.4862	1.6022	1.6321	1.6701	1.7671	1.8775
1 3/4	1.6198	1.6355	1.7691	1.8039	1.8484	1.9634	2.0984
1 7/8	1.7671	1.7847	1.9360	1.9757	2.0267	2.1598	2.3193
2	1.9144	1.9339	2.1029	2.1475	2.2050	2.3561	2.5402
2 1/8	2.0616	2.0831	2.2698	2.3193	2.3833	2.5525	2.7611
2 1/4	2.2089	2.2324	2.4366	2.4911	2.5616	2.7488	2.9820
2 3/8	2.3561	2.3816	2.6035	2.6629	2.7398	2.9452	3.2029
2 1/2	2.5034	2.5308	2.7704	2.8347	2.9181	3.1415	3.4238
2 5/8	2.6507	2.6800	2.9373	3.0066	3.0964	3.3379	3.6447
2 3/4	2.7979	2.8293	3.1042	3.1784	3.2747	3.5342	3.8656
2 7/8	2.9452	2.9785	3.2711	3.3502	3.4530	3.7306	4.0865
3	3.0925	3.1277	3.4380	3.5220	3.6313	3.9269	4.3074
3 1/8	3.2397	3.2769	3.6049	3.6938	3.8096	4.1233	4.5283
3 1/4	3.3870	3.4262	3.7718	3.8656	3.9878	4.3196	4.7492
3 3/8	3.5342	3.5754	3.9387	4.0374	4.1661	4.5160	4.9700
3 1/2	3.6815	3.7246	4.1056	4.2092	4.3444	4.7123	5.1909
3 5/8	3.8288	3.8738	4.2725	4.3810	4.5227	4.9087	5.4118
3 3/4	3.9760	4.0231	4.4394	4.5528	4.7010	5.1050	5.6327
3 7/8	4.1233	4.1723	4.6063	4.7246	4.8793	5.3014	5.8536
4	4.2706	4.3215	4.7732	4.8964	5.0576	5.4977	6.0745
4 1/8	4.4178	4.4708	4.9401	5.0682	5.2358	5.6941	6.2954
4 1/4	4.5651	4.6200	5.1070	5.2400	5.4141	5.8904	6.5163
4 3/8	4.7123	4.7692	5.2739	5.4118	5.5924	6.0868	6.7372
4 1/2	4.8596	4.9184	5.4408	5.5836	5.7707	6.2831	6.9581
4 5/8	5.0069	5.0677	5.6077	5.7554	5.9490	6.4795	7.1790
4 3/4	5.1541	5.2169	5.7746	5.9273	6.1273	6.6758	7.3999
4 7/8	5.3014	5.3661	5.9415	6.0991	6.3055	6.8722	7.6208
5	5.4487	5.5153	6.1084	6.2709	6.4838	7.0685	7.8417
5 1/8	5.5959	5.6646	6.2753	6.4427	6.6621	7.2649	8.0626
5 1/4	5.7432	5.8138	6.4422	6.6145	6.8404	7.4612	8.2834
5 3/8	5.8904	5.9630	6.6091	6.7863	7.0187	7.6576	8.5043
5 1/2	6.0377	6.1122	6.7760	6.9581	7.1970	7 8539	8.7252
5 3/4	6.3322	6.4107	7.1098	7.3017	7.5535	8.2466	9.1670
6	6.6267	6.7091	7.4436	7.6453	7.9101	8.6393	9.6088
6 1/4	6.9213	7.0076	7.7774	7.9889	8.2667	9.0320	10.0506
6 1/2	7.2158	7.3060	8.1112	8.3325	8.6233	9.4247	10.4924
6 3/4	7.5103	7.6045	8.4449	8.6761	8.9798	9.8174	10.9342
7	7.8048	7.9029	8.7787	9.0198	9.3364	10.2101	11.3760
7 1/4	8.0994	8.2014	9.1125	9.3634	9.6930	10.6028	11.8177
7 1/2	8.3939	8.4998	9.4463	9.7070	10.0495	10.9955	12.2595
7 3/4	8.6884	8.7983	9.7801	10.0506	10.4061	11.3882	12.7013
8	8.9829	9.0967	10.1139	10.3942	10.7627	11.7809	13.1431
8 1/4	9.2775	9.3952	10.4477	10.7378	11.1193	12.1736	13.5849
8 1/2	9.5720	9.6936	10.7815	11.0814	11.4758	12.5663	14.0267
8 3/4	9.8665	9.9921	11.1153	11.4250	11.8324	12.9590	14.4685
9	10.1610	10.2906	11.4491	11.7687	12.1890	13.3517	14.9102
9 1/4	10.4556	10.5891	11.7830	12.1123	12.5456	13.7445	15.3521
9 1/2	10.7502	10.8875	12.1168	12.4560	12.9022	14.1372	15.7939
9 3/4	11.0447	11.1860	12.4506	12.7996	13.2588	14.5299	16.2357
10	11.3392	11.4844	12.7843	13.1432	13.6153	14.9226	16.6775
10 1/4	11.6337	11.7829	13.1181	13.4868	13.9719	15.3153	17.1193
10 1/2	11.9283	12.0813	13.4519	13.8304	14.3285	15.7080	17.5611
10 3/4	12.2228	12.3798	13.7857	14.1740	14.6850	16.1007	18.0028
11	12.5173	12.6782	14.1195	14.5176	15.0416	16.4934	18.4446
11 1/4	12.8118	12.9767	14.4533	14.8612	15.3982	16.8861	18.8864
11 1/2	13.1064	13.2751	14.7871	15.2049	15.7548	17.2788	19.3282
11 3/4	13.4009	13.5736	15.1209	15.5485	16.1113	17.6715	19.7700
12	13.6954	13.8720	15.4547	15.8921	16.4679	18.0642	20.2118
12 1/4	13.9899	14.1705	15.7885	16.2357	16.8245	18.4569	20.6536
12 1/2	14.2845	14.4690	16.1223	16.5793	17.1810	18.8496	21.0954
12 3/4	14.5790	14.7674	16.4561	16.9229	17.5376	19.2423	21.5371
13	....	....	....	17.2665	17.8942	19.6350	21.9789
13 1/4	....	....	....	17.6101	18.2508	20.0277	22.4207
13 1/2	....	....	....	17.9538	18.6073	20.4204	22.8625
13 3/4	....	....	....	....	....	20.8131	23.3043

SECTIONAL AREA OF WALL IN SQUARE INCHES

(Continued)

Outside Diameter Inches	THICKNESS IN FRACTIONS OF AN INCH						
	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
1 7/16	1.5953	....	....	....	....	....	....
1 1/2	1.7180	....	....	....	....	....	....
1 5/8	1.9634	....	....	....	....	....	....
1 3/4	2.2089	....	....	....	....	....	....
1 7/8	2.4543	....	....	....	....	....	....
2	2.6998	....	....	....	....	....	....
2 1/8	2.9452	3.1047	3.2397	3.3502	3.4361	3.4974	3.5342
2 1/4	3.1906	3.3747	3.5342	3.6692	3.7797	3.8656	3.9269
2 3/8	3.4361	3.6447	3.8288	3.9883	4.1233	4.2337	4.3196
2 1/2	3.6815	3.9147	4.1233	4.3074	4.4669	4.6019	4.7123
2 5/8	3.9269	4.1847	4.4178	4.6264	4.8105	4.9700	5.1050
2 3/4	4.1724	4.4546	4.7123	4.9455	5.1541	5.3382	5.4977
2 7/8	4.4178	4.7246	5.0069	5.2646	5.4977	5.7064	5.8904
3	4.6633	4.9946	5.3014	5.5836	5.8413	6.0745	6.2831
3 1/8	4.9087	5.2646	5.5959	5.9027	6.1850	6.4427	6.6758
3 1/4	5.1541	5.5346	5.8904	6.2218	6.5286	6.8108	7.0685
3 3/8	5.3996	5.8045	6.1850	6.5408	6.8722	7.1790	7.4612
3 1/2	5.6450	6.0745	6.4795	6.8599	7.2158	7.5471	7.8539
3 5/8	5.8904	6.3445	6.7740	7.1790	7.5594	7.9153	8.2466
3 3/4	6.1359	6.6145	7.0685	7.4980	7.9030	8.2834	8.6393
3 7/8	6.3813	6.8845	7.3631	7.8171	8.2466	8.6516	9.0320
4	6.6267	7.1544	7.6576	8.1362	8.5902	9.0198	9.4247
4 1/8	6.8722	7.4244	7.9521	8.4553	8.9339	9.3879	9.8174
4 1/4	7.1176	7.6944	8.2466	8.7743	9.2775	9.7561	10.2101
4 3/8	7.3631	7.9644	8.5412	9.0934	9.6211	10.1242	10.6028
4 1/2	7.6085	8.2344	8.8357	9.4125	9.9647	10.4924	10.9955
4 5/8	7.8539	8.5043	9.1302	9.7315	10.3083	10.8605	11.3882
4 3/4	8.0994	8.7743	9.4247	10.0506	10.6519	11.2287	11.7809
4 7/8	8.3448	9.0443	9.7193	10.3697	10.9955	11.5968	12.1736
5	8.5902	9.3143	10.0138	10.6887	11.3391	11.9650	12.5663
5 1/8	8.8357	9.5843	10.3083	11.0078	11.6827	12.3332	12.9590
5 1/4	9.0811	9.8542	10.6028	11.3269	12.0264	12.7013	13.3517
5 3/8	9.3266	10.1242	10.8974	11.6459	12.3700	13.0695	13.7444
5 1/2	9.5720	10.3942	11.1919	11.9650	12.7136	13.4376	14.1371
5 3/4	10.0629	10.9342	11.7809	12.6031	13.4008	14.1739	14.9225
6	10.5537	11.4741	12.3700	13.2413	14.0880	14.9102	15.7079
6 1/4	11.0446	12.0141	12.9590	13.8794	14.7753	15.6466	16.4933
6 1/2	11.5355	12.5540	13.5481	14.5175	15.4625	16.3829	17.2787
6 3/4	12.0264	13.0940	14.1371	15.1557	16.1497	17.1192	18.0641
7	12.5172	13.6340	14.7262	15.7938	16.8369	17.8555	18.8495
7 1/4	13.0081	14.1739	15.3152	16.4320	17.5241	18.5918	19.6349
7 1/2	13.4990	14.7139	15.9043	17.0701	18.2114	19.3281	20.4203
7 3/4	13.9899	15.2539	16.4933	17.7082	18.8986	20.0644	21.2057
8	14.4807	15.7938	17.0824	18.3464	19.5858	20.8007	21.9911
8 1/4	14.9716	16.3338	17.6714	18.9845	20.2730	21.5370	22.7765
8 1/2	15.4625	16.8737	18.2605	19.6226	20.9603	22.2734	23.5619
8 3/4	15.9534	17.4137	18.8495	20.2608	21.6475	23.0097	24.3473
9	16.4442	17.9537	19.4386	20.8989	22.3347	23.7460	25.1327
9 1/4	16.9352	18.4937	20.0277	21.5371	23.0220	24.4824	25.9182
9 1/2	17.4261	19.0337	20.6168	22.1753	23.7093	25.2187	26.7036
9 3/4	17.9169	19.5736	21.2058	22.8134	24.3965	25.9550	27.4890
10	18.4078	20.1136	21.7949	23.4516	25.0837	26.6913	28.2744
10 1/4	18.8987	20.6536	22.3839	24.0897	25.7709	27.4276	29.0598
10 1/2	19.3896	21.1935	22.9730	24.7278	26.4582	28.1640	29.8452
10 3/4	19.8804	21.7335	23.5620	25.3660	27.1454	28.9003	30.6306
11	20.3713	22.2735	24.1511	26.0041	27.8326	29.6366	31.4160
11 1/4	20.8622	22.8134	24.7401	26.6422	28.5198	30.3729	32.2014
11 1/2	21.3531	23.3534	25.3292	27.2804	29.2071	31.1092	32.9868
11 3/4	21.8439	23.8933	25.9182	27.9185	29.8943	31.8455	33.7722
12	22.3348	24.4333	26.5073	28.5567	30.5815	32.5818	34.5576
12 1/4	22.8257	24.9733	27.0963	29.1948	31.2687	33.3181	35.3430
12 1/2	23.3166	25.5132	27.6854	29.8329	31.9559	34.0545	36.1284
12 3/4	23.8074	26.0532	28.2744	30.4711	32.6432	34.7908	36.9138
13	24.2983	26.5932	28.8635	31.1092	33.3304	35.5271	37.6992
13 1/4	24.7892	27.1331	29.4525	31.7473	34.0176	36.2634	38.4846
13 1/2	25.2801	27.6731	30.0416	32.3855	34.7049	36.9997	39.2700
13 3/4	25.7709	28.2130	30.6306	33.0236	35.3921	37.7360	40.0554
14	26.2618	28.7530	31.2197	33.6618	36.0793	38.4723	40.8408

MOMENT OF INERTIA, I FOR NEUTRAL AXIS THROUGH CENTER OF SECTION

Outside Diameter Inches	THICKNESS IN GAGES 24 B.W.G.	23 B.W.G.	22 B.W.G.	21 B.W.G.	20 B.W.G.	19 B.W.G.	18 B.W.G.	17 B.W.G.
1/4	.0001	.0001	.0001	.0001	.0001	.0001	.0001	.0001
5/16	.0002	.0002	.0002	.0002	.0002	.0003	.0003	.0003
3/8	.0003	.0004	.0004	.0005	.0005	.0006	.0006	.0007
7/16	.0006	.0006	.0007	.0008	.0009	.0010	.0011	.0012
1/2	.0009	.0010	.0011	.0012	.0013	.0015	.0017	.0020
9/16	.0013	.0015	.0016	.0018	.0020	.0023	.0026	.0029
5/8	.0018	.0021	.0023	.0026	.0028	.0032	.0037	.0041
11/16	.0025	.0028	.0031	.0035	.0038	.0044	.0050	.0057
3/4	.0033	.0037	.0041	.0046	.0050	.0058	.0066	.0076
13/16	.0042	.0047	.0053	.0059	.0064	.0075	.0085	.0098
7/8	.0053	.0060	.0066	.0075	.0081	.0095	.0108	.0124
15/16	.0066	.0074	.0082	.0093	.0101	.0118	.0135	.0155
1	.0080	.0091	.0101	.0114	.0123	.0145	.0165	.0191
1 1/16	.0097	.0109	.0121	.0137	.0149	.0175	.0200	.0231
1 1/8	.0115	.0130	.0145	.0164	.0178	.0209	.0240	.0277
1 3/16	.0136	.0154	.0171	.0194	.0210	.0248	.0284	.0329
1 1/4	.0160	.0180	.0200	.0227	.0246	.0291	.0333	.0386
1 5/16	.0185	.0209	.0233	.0264	.0286	.0338	.0388	.0450
1 3/8	.0214	.0241	.0268	.0304	.0330	.0391	.0449	.0521
1 7/16	.0245	.0276	.0308	.0349	.0379	.0448	.0515	.0598
1 1/2	.0279	.0315	.0350	.0397	.0432	.0511	.0588	.0684
1 5/8	.0355	.0402	.0447	.0508	.0552	.0654	.0753	.0877
1 3/4	.0445	.0504	.0561	.0637	.0693	.0822	.0947	.1104
1 7/8	.0549	.0621	.0692	.0786	.0856	.1016	.1172	.1367
2	.0668	.0756	.0843	.0958	.1043	.1238	.1429	.1669
2 1/8	....	....	....	....	....	....	.1722	.2013
2 1/4	....	....	....	....	....	....	.2052	.2400
2 3/8	....	....	....	....	....	....	.2422	.2834
2 1/2	....	....	....	....	....	....	.2834	.3318
2 5/8	....	....	....	....	....	....	.3290	.3854
2 3/4	....	....	....	....	....	....	.3792	.4445
2 7/8	....	....	....	....	....	....	.4344	.5093
3	....	....	....	....	....	....	.4946	.5802
3 1/8	....	....	....	....	....	....	.5601	.6573
3 1/4	....	....	....	....	....	....	.6312	.7410

MOMENT OF INERTIA, I, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES							
	16 B.W.G.	15 B.W.G.	14 B.W.G.	13 B.W.G.	12 B.W.G.	11 B.W.G.	10 B.W.G.	9 B.W.G.
1/4	.0001	.0001	.0001	.0001	....	....	....	....
5/16	.0004	.0004	.0004	.0004	.0004	.0004	....	....
3/8	.0007	.0008	.0008	.0009	.0009	.0009	.0009	....
7/16	.0013	.0014	.0015	.0016	.0016	.0017	.0017	....
1/2	.0021	.0022	.0024	.0026	.0027	.0028	.0029	.0029
9/16	.0031	.0034	.0037	.0039	.0042	.0043	.0045	.0046
5/8	.0045	.0048	.0053	.0057	.0061	.0064	.0066	.0069
11/16	.0062	.0066	.0073	.0079	.0085	.0089	.0094	.0098
3/4	.0082	.0089	.0098	.0107	.0116	.0122	.0128	.0134
13/16	.0107	.0115	.0128	.0140	.0152	.0161	.0170	.0178
7/8	.0136	.0147	.0163	.0179	.0196	.0207	.0221	.0232
15/16	.0170	.0184	.0205	.0225	.0247	.0263	.0280	.0296
1	.0209	.0227	.0253	.0279	.0307	.0327	.0349	.0370
1 1/16	.0254	.0276	.0308	.0341	.0375	.0400	.0429	.0456
1 1/8	.0305	.0331	.0371	.0411	.0454	.0485	.0521	.0554
1 3/16	.0362	.0394	.0441	.0490	.0542	.0580	.0625	.0666
1 1/4	.0426	.0463	.0520	.0578	.0641	.0687	.0741	.0791
1 5/16	.0496	.0541	.0608	.0677	.0752	.0807	.0872	.0932
1 3/8	.0575	.0627	.0705	.0786	.0874	.0939	.1017	.1089
1 7/16	.0661	.0721	.0813	.0907	.1010	.1086	.1177	.1262
1 1/2	.0755	.0825	.0930	.1039	.1159	.1247	.1354	.1453
1 5/8	.0970	.1061	.1198	.1341	.1499	.1616	.1758	.1891
1 3/4	.1222	.1338	.1513	.1696	.1899	.2051	.2235	.2409
1 7/8	.1515	.1659	.1879	.2109	.2366	.2559	.2793	.3015
2	.1851	.2029	.2300	.2585	.2904	.3143	.3436	.3715
2 1/4	.2665	.2924	.3321	.3740	.4211	.4568	.5005	.5424
2 3/8	.3148	.3456	.3929	.4429	.4991	.5418	.5943	.6447
2 1/2	.3687	.4050	.4607	.5197	.5863	.6369	.6991	.7591
2 5/8	.4285	.4708	.5359	.6050	.6830	.7424	.8157	.8864
2 3/4	.4943	.5434	.6189	.6990	.7898	.8590	.9445	1.0271
2 7/8	.5666	.6230	.7100	.8024	.9072	.9872	1.0862	1.1821
3	.6456	.7101	.8096	.9155	1.0357	1.1276	1.2414	1.3518
3 1/4	.8250	.9079	1.0360	1.1726	1.3280	1.4471	1.5949	1.7387
3 3/8	.9260	1.0193	1.1635	1.3175	1.4928	1.6273	1.7945	1.9571
3 1/2	1.0349	1.1394	1.3011	1.4739	1.6707	1.8219	2.0099	2.1932
3 5/8	1.1520	1.2686	1.4491	1.6421	1.8623	2.0314	2.2420	2.4474
3 3/4	1.2776	1.4073	1.6080	1.8228	2.0679	2.2565	2.4914	2.7207
3 7/8	1.4121	1.5557	1.7780	2.0161	2.2881	2.4975	2.7585	3.0135
4	1.5557	1.7141	1.9597	2.2228	2.5235	2.7551	3.0441	3.3267
4 1/4	1.8713	2.0626	2.3592	2.6774	3.0416	3.3224	3.6732	4.0167
4 1/2	2.2271	2.4554	2.8097	3.1902	3.6261	3.9626	4.3835	4.7961
4 3/4	2.6253	2.8951	3.3142	3.7646	4.2811	4.6803	5.1799	5.6703
5	3.0683	3.3845	3.8758	4.4041	5.0106	5.4797	6.0675	6.6448
5 1/4	3.5586	3.9261	4.4974	5.1123	5.8186	6.3654	7.0510	7.7251
5 1/2	4.0985	4.5226	5.1822	5.8925	6.7092	7.3418	8.1355	8.9166
5 3/4	....	....	....	....	....	....	9.3259	10.2247
6	....	....	....	....	....	....	10.6271	11.6550
6 1/4	....	....	....	....	....	....	12.0441	13.2127
6 1/2	....	....	....	....	....	....	13.5817	14.9035
6 3/4	....	....	....	....	....	....	15.2450	16.7327
7	....	....	....	....	....	....	17.0389	18.7058
7 1/4	....	....	....	....	....	....	18.9682	20.8282
7 1/2	....	....	....	....	....	....	21.0379	23.1054
7 3/4	....	....	....	....	....	....	23.2530	25.5428
8	....	....	....	....	....	....	25.6184	28.1460
8 1/4	....	....	....	....	....	....	28.1390	30.9202
8 1/2	....	....	....	....	....	....	30.8197	33.8711
8 3/4	....	....	....	....	....	....	33.6656	37.0039
9	....	....	....	....	....	....	36.6814	40.3243

MOMENT OF INERTIA, I, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	5/32"	8 B.W.G.	7 B.W.G.	3/16"	6 B.W.G.	7/32"	5 B.W.G.	4 B.W.G.
5/8	.0070	.0071	.0072	.0072	....	....	....	....
11/16	.0099	.0101	.0104	.0104	.0106	.0107	.0107	.0108
3/4	.0137	.0140	.0143	.0145	.0148	.0150	.0150	.0152
13/16	.0183	.0187	.0193	.0195	.0200	.0204	.0204	.0207
7/8	.0238	.0244	.0253	.0257	.0263	.0269	.0270	.0275
15/16	.0304	.0312	.0324	.0330	.0340	.0348	.0349	.0356
1	.0381	.0391	.0408	.0415	.0429	.0441	.0442	.0453
1 1/16	.0470	.0484	.0506	.0515	.0534	.0550	.0551	.0567
1 1/8	.0572	.0590	.0618	.0630	.0655	.0676	.0678	.0699
1 3/16	.0688	.0710	.0745	.0762	.0793	.0820	.0822	.0850
1 1/4	.0819	.0846	.0890	.0910	.0949	.0984	.0987	.1022
1 5/16	.0965	.0999	.1052	.1077	.1125	.1168	.1172	.1216
1 3/8	.1129	.1169	.1233	.1263	.1321	.1375	.1379	.1433
1 7/16	.1309	.1357	.1434	.1470	.1540	.1605	.1610	.1676
1 1/2	.1508	.1565	.1655	.1698	.1781	.1859	.1865	.1945
1 5/8	.1966	.2042	.2165	.2224	.2338	.2446	.2454	.2567
1 3/4	.2507	.2608	.2771	.2849	.3002	.3147	.3158	.3310
1 7/8	.3141	.3270	.3481	.3581	.3781	.3974	.3985	.4186
2	.3873	.4035	.4303	.4431	.4684	.4928	.4946	.5206
2 1/8	.4711	.4913	.5245	.5405	.5723	.6028	.6052	.6379
2 1/4	.5663	.5909	.6317	.6513	.6904	.7282	.7312	.7718
2 3/8	.6735	.7032	.7525	.7763	.8239	.8700	.8736	.9234
2 1/2	.7934	.8290	.8879	.9165	.9736	1.0292	1.0335	1.0936
2 5/8	.9269	.9689	1.0387	1.0726	1.1405	1.2067	1.2118	1.2837
2 3/4	1.0745	1.1238	1.2057	1.2455	1.3255	1.4036	1.4096	1.4947
2 7/8	1.2371	1.2943	1.3897	1.4362	1.5295	1.6208	1.6279	1.7277
3	1.4153	1.4813	1.5916	1.6453	1.7535	1.8595	1.8677	1.9839
3 1/8	1.6099	1.6856	1.8122	1.8739	1.9984	2.1206	2.1301	2.2642
3 1/4	1.8215	1.9078	2.0522	2.1228	2.2651	2.4050	2.4159	2.5698
3 3/8	2.0509	2.1488	2.3127	2.3928	2.5546	2.7139	2.7263	2.9018
3 1/2	2.2989	2.4093	2.5943	2.6848	2.8678	3.0482	3.0623	3.2613
3 5/8	2.5661	2.6900	2.8979	2.9997	3.2056	3.4089	3.4248	3.6494
3 3/4	2.8532	2.9917	3.2243	3.3383	3.5691	3.7971	3.8149	4.0671
3 7/8	3.1610	3.3153	3.5744	3.7015	3.9590	4.2137	4.2336	4.5156
4	3.4902	3.6613	3.9489	4.0901	4.3764	4.6597	4.6819	4.9960
4 1/8	3.8416	4.0307	4.3488	4.5051	4.8221	5.1362	5.1608	5.5094
4 1/4	4.2157	4.4241	4.7749	4.9472	5.2972	5.6442	5.6713	6.0568
4 3/8	4.6134	4.8423	5.2278	5.4174	5.8025	6.1846	6.2145	6.6393
4 1/2	5.0354	5.2861	5.7086	5.9165	6.3389	6.7585	6.7914	7.2582
4 5/8	5.4823	5.7562	6.2181	6.4454	6.9075	7.3668	7.4029	7.9143
4 3/4	5.9550	6.2535	6.7570	7.0049	7.5092	8.0107	8.0500	8.6089
4 7/8	6.4541	6.7785	7.3261	7.5959	8.1448	8.6910	8.7339	9.3430
5	6.9803	7.3322	7.9264	8.2192	8.8154	9.4089	9.4555	10.1178
5 1/4	8.1171	8.5285	9.2236	9.5664	10.2649	10.9611	11.0158	11.7936
5 1/2	9.3710	9.8483	10.6552	11.0534	11.8654	12.6754	12.7390	13.6451
5 3/4	10.7480	11.2977	12.2278	12.6871	13.6242	14.5598	14.6333	15.6809
6	12.2536	12.8828	13.9481	14.4744	15.5488	16.6224	16.7068	17.9100
6 1/4	13.8937	14.6098	15.8226	16.4222	17.6467	18.8712	18.9675	20.3410
6 1/2	15.6740	16.4845	17.8581	18.5373	19.9254	21.3143	21.4236	22.9828
6 3/4	17.6003	18.5132	20.0610	20.8268	22.3923	23.9598	24.0832	25.8439
7	19.6783	20.7020	22.4381	23.2975	25.0550	26.8156	26.9543	28.9334
7 1/4	21.9138	23.0567	25.0635	25.9562	27.9208	29.8899	30.0450	32.2598
7 1/2	24.3125	25.5837	27.7413	28.8100	30.9973	33.1907	33.3636	35.8320
7 3/4	26.8802	28.2889	30.6807	31.8657	34.2920	36.7261	36.9179	39.6587
8	29.6226	31.1783	33.8207	35.1302	37.8122	40.5041	40.7163	43.7487
8 1/4	32.5455	34.2582	37.1679	38.6104	41.5656	44.5327	44.7667	48.1108
8 1/2	35.6546	37.5345	40.7291	42.3133	45.5595	48.8200	49.0772	52.7536
8 3/4	38.9557	41.0133	44.5109	46.2456	49.8014	53.3742	53.6560	57.6860
9	42.4546	44.7007	48.5198	50.4144	54.2088	58.2031	58.5111	62.9168
9 1/4	....	....	....	....	59.0745	63.3312	63.6671	68.4723
9 1/2	....	....	....	....	....	....	69.1006	74.3275
9 3/4	....	....	....	....	....	....	74.8349	80.5075
10	....	....	....	....	....	....	80.8780	87.0208
10 1/4	....	....	....	....	....	....	....	93.8764
10 1/2	....	....	....	....	....	....	....	101.0830

MOMENT OF INERTIA, I, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	1/4"	3 B.W.G.	9/32"	2 B.W.G.	1 B.W.G.	5/16"	0 B.W.G.	11/32"
11/16	.0109	....	....	....	....	....	....	....
3/4	.0153	.0153	.0154	.0154	.0155	.0155	....	....
13/16	.0209	.0210	.0212	.0212	.0212	.0213	.0213	.0213
7/8	.0278	.0279	.0283	.0283	.0284	.0285	.0287	.0287
15/16	.0361	.0363	.0369	.0370	.0372	.0374	.0377	.0377
1	.0460	.0464	.0472	.0473	.0478	.0481	.0485	.0486
1 1/16	.0576	.0582	.0594	.0596	.0603	.0607	.0615	.0615
1 1/8	.0711	.0719	.0737	.0739	.0748	.0755	.0767	.0768
1 3/16	.0866	.0877	.0901	.0903	.0917	.0926	.0943	.0945
1 1/4	.1043	.1057	.1088	.1092	.1110	.1123	.1146	.1149
1 5/16	.1242	.1261	.1301	.1305	.1330	.1347	.1378	.1381
1 3/8	.1466	.1489	.1540	.1546	.1577	.1599	.1640	.1644
1 7/16	.1716	.1745	.1808	.1815	.1854	.1882	.1934	.1940
1 1/2	.1994	.2028	.2105	.2114	.2162	.2197	.2263	.2271
1 5/8	.2636	.2685	.2797	.2810	.2880	.2931	.3031	.3043
1 3/4	.3405	.3472	.3627	.3645	.3745	.3817	.3960	.3978
1 7/8	.4312	.4402	.4610	.4634	.4769	.4868	.5066	.5090
2	.5368	.5486	.5757	.5789	.5968	.6099	.6363	.6397
2 1/8	.6586	.6735	.7083	.7124	.7354	.7524	.7869	.7913
2 1/4	.7976	.8163	.8599	.8651	.8942	.9157	.9598	.9654
2 3/8	.9550	.9780	1.0320	1.0384	1.0745	1.1014	1.1566	1.1637
2 1/2	1.1320	1.1599	1.2257	1.2335	1.2777	1.3107	1.3788	1.3877
2 5/8	1.3297	1.3632	1.4424	1.4518	1.5052	1.5453	1.6282	1.6389
2 3/4	1.5493	1.5890	1.6833	1.6946	1.7585	1.8064	1.9061	1.9191
2 7/8	1.7918	1.8386	1.9499	1.9632	2.0387	2.0956	2.2141	2.2296
3	2.0586	2.1132	2.2432	2.2588	2.3474	2.4142	2.5540	2.5723
3 1/8	2.3506	2.4139	2.5648	2.5829	2.6860	2.7638	2.9271	2.9485
3 1/4	2.6691	2.7419	2.9157	2.9366	3.0557	3.1457	3.3350	3.3599
3 3/8	3.0152	3.0984	3.2974	3.3214	3.4580	3.5615	3.7794	3.8081
3 1/2	3.3900	3.4846	3.7112	3.7385	3.8943	4.0124	4.2618	4.2947
3 5/8	3.7948	3.9018	4.1582	4.1892	4.3659	4.5001	4.7837	4.8212
3 3/4	4.2307	4.3510	4.6399	4.6748	4.8742	5.0258	5.3468	5.3893
3 7/8	4.6987	4.8335	5.1576	5.1967	5.4207	5.5911	5.9525	6.0004
4	5.2001	5.3505	5.7124	5.7561	6.0066	6.1974	6.6025	6.6562
4 1/8	5.7361	5.9032	6.3057	6.3544	6.6334	6.8461	7.2983	7.3583
4 1/4	6.3077	6.4927	6.9388	6.9929	7.3024	7.5387	8.0415	8.1083
4 3/8	6.9161	7.1203	7.6130	7.6728	8.0151	8.2766	8.8336	8.9077
4 1/2	7.5625	7.7871	8.3297	8.3954	8.7728	9.0612	9.6763	9.7581
4 5/8	8.2480	8.4944	9.0899	9.1622	9.5768	9.8939	10.5710	10.6611
4 3/4	8.9737	9.2433	9.8952	9.9744	10.4287	10.7763	11.5193	11.6183
4 7/8	9.7409	10.0351	10.7468	10.8332	11.3296	11.7098	12.5231	12.6313
5	10.5507	10.8708	11.6459	11.7400	12.2811	12.6957	13.5832	13.7016
5 1/8	11.4041	11.7518	12.5938	12.6962	13.2846	13.7356	14.7018	14.8308
5 1/4	12.3025	12.6791	13.5919	13.7030	14.3413	14.8308	15.8803	16.0205
5 1/2	14.2384	14.6778	15.7438	15.8736	16.6201	17.1932	18.4233	18.5879
5 3/4	16.3675	16.8763	18.1118	18.2624	19.1286	19.7942	21.2247	21.4162
6	18.6992	19.2843	20.7064	20.8797	21.8779	22.6455	24.2969	24.5182
6 1/4	21.2425	21.9113	23.5377	23.7361	24.8791	25.7585	27.6526	27.9065
6 1/2	24.0068	24.7667	26.6163	26.8421	28.1430	29.1448	31.3041	31.5939
6 3/4	27.0011	27.8602	29.9525	30.2080	31.6809	32.8158	34.2641	35.5928
7	30.2347	31.2013	33.5566	33.8443	35.5038	36.7831	39.5450	39.9161
7 1/4	33.7168	34.7995	37.4389	37.7615	39.6226	41.0581	44.1593	44.5763
7 1/2	37.4567	38.6643	41.6099	41.9700	44.0485	45.6524	49.1197	49.5861
7 3/4	41.4634	42.8053	46.0799	46.4804	48.7925	50.5774	54.4385	54.9581
8	45.7463	47.2320	50.8592	51.3030	53.8656	55.8447	60.1284	60.7051
8 1/4	50.3145	51.9540	55.9581	56.4482	59.2789	61.4658	66.2018	66.8396
8 1/2	55.1772	56.9807	61.3872	61.9267	65.0434	67.4521	72.6712	73.3744
8 3/4	60.3437	62.3218	67.1566	67.7487	71.1702	73.8153	79.5492	80.3221
9	65.8231	67.9867	73.2768	73.9249	77.6703	80.5667	86.8483	87.6952
9 1/4	71.6430	74.0040	79.7786	80.4862	84.5765	87.7406	94.6053	95.5313
9 1/2	77.7774	80.3469	86.6331	87.4037	91.8582	95.3050	102.7862	103.7956
9 3/4	84.2526	87.0423	93.8697	94.7066	99.5464	103.2924	111.4258	112.5236
10	91.0774	94.0998	101.4983	102.4055	107.6522	111.7142	120.5367	121.7278
10 1/4	98.2614	101.5289	109.5296	110.5109	116.1867	120.5819	130.1314	131.4210
10 1/2	105.8136	109.3392	117.9740	119.0332	125.1609	129.9071	140.2225	141.6158
10 3/4	....	117.5403	126.8416	127.9829	134.5858	139.7012	150.8223	152.3248
11	....	126.1415	136.1430	137.3703	144.4725	149.9758	161.9435	163.5608
11 1/4	....	135.1525	145.8885	147.2060	154.8321	160.7423	173.5986	175.3363
11 1/2	....	144.5828	156.0882	157.5006	165.6755	172.0123	185.8001	187.6641
11 3/4	....	154.4420	166.7530	168.2643	177.0138	183.7973	198.5605	200.5566
12	....	164.7396	177.8926	179.5077	188.8582	196.1087	211.8923	214.0269

MOMENT OF INERTIA, I, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH						
	3/8"	00 B.W.G.	000 B.W.G.	7/16"	0000 B.W.G.	1/2"	9/16"
13/16	.0213	....	....	....	....	....	....
7/8	.0287	....	....	....	....	....	....
15/16	.0378	.0378	.0379	.0379	....	....	....
1	.0488	.0489	.0490	.0490	.0490	....	....
1 1/16	.0620	.0621	.0624	.0624	.0625	....	....
1 1/8	.0776	.0777	.0783	.0784	.0785	.0786	....
1 3/16	.0958	.0959	.0969	.0971	.0973	.0975	....
1 1/4	.1167	.1170	.1185	.1188	.1191	.1196	....
1 5/16	.1407	.1410	.1434	.1438	.1443	.1452	....
1 3/8	.1679	.1684	.1717	.1723	.1731	.1744	.1752
1 7/16	.1986	.1992	.2037	.2046	.2057	.2078	.2091
1 1/2	.2329	.2337	.2397	.2410	.2424	.2454	.2475
1 5/8	.3135	.3148	.3245	.3267	.3293	.3347	.3392
1 3/4	.4112	.4132	.4281	.4316	.4357	.4448	.4528
1 7/8	.5280	.5308	.5525	.5576	.5637	.5779	.5911
2	.6655	.6693	.6995	.7067	.7155	.7363	.7566
2 1/8	.8254	.8305	.8712	.8810	.8932	.9223	.9518
2 1/4	1.0095	1.0161	1.0694	1.0825	1.0988	1.1382	1.1794
2 3/8	1.2195	1.2278	1.2963	1.3132	1.3344	1.3863	1.4419
2 1/2	1 4570	1.4675	1.5536	1.5751	1.6021	1.6689	1.7420
2 5/8	1.7240	1.7368	1.8434	1.8703	1.9040	1.9884	2.0822
2 3/4	2.0219	2.0375	2.1676	2.2006	2.2422	2.3469	2.4650
2 7/8	2.3527	2.3714	2.5282	2.5682	2.6188	2.7469	2.8932
3	2.7180	2.7402	2.9272	2.9751	3.0358	3.1906	3.3693
3 1/8	3.1195	3.1456	3.3664	3.4232	3.4954	3.6804	3.8959
3 1/4	3.5590	3.5895	3.8479	3.9147	3.9997	4.2184	4.4755
3 3/8	4.0382	4.0735	4.3735	4.4514	4.5506	4.8071	5.1108
3 1/2	4.5587	4.5994	4.9454	5.0354	5.1504	5.4487	5.8043
3 5/8	5.1225	5.1689	5.5653	5.6688	5.8011	6.1455	6.5587
3 3/4	5.7311	5.7838	6.2353	6.3535	6.5048	6.8998	7.3765
3 7/8	6.3863	6.4459	6.9574	7.0916	7.2636	7.7140	8.2603
4	7.0898	7.1569	7.7334	7.8850	8.0796	8.5902	9.2126
4 1/8	7.8434	7.9185	8.5653	8.7358	8.9549	9.5310	10.2362
4 1/4	8.6487	8.7326	9.4552	9.6460	9.8915	10.5384	11.3336
4 3/8	9.5076	9.6007	10.4049	10.6176	10.8915	11 6149	12.5073
4 1/2	10.4216	10.5248	11.4164	11.6526	11.9571	12.7627	13.7599
4 5/8	11.3926	11.5064	12.4916	12.7531	13.0903	13.9841	15.0941
4 3/4	12.4223	12.5475	13.6326	13.9210	14.2932	15.2815	16.5125
4 7/8	13.5124	13.6497	14.8413	15.1584	15.5680	16.6571	18.0175
5	14.6646	14.8148	16.1195	16.4672	16.9166	18.1132	19.6119
5 1/8	15.8807	16.0445	17.4694	17.8496	18.3412	19.6522	21.2981
5 1/4	17.1623	17.3406	18.8928	19.3074	19.8439	21.2763	23.0789
5 3/8	18.5113	18.7049	20.3917	20.8427	21.4267	22.9878	24.9567
5 1/2	19.9292	20.1390	21.9680	22.4576	23.0918	24.7891	26.9341
5 3/4	22.9792	23.2239	25.3609	25.9340	26.6771	28.6701	31.1984
6	26.3259	26.6092	29.0870	29.7526	30.6165	32.9376	35.8924
6 1/4	29.9833	30.3091	33.1621	33.9297	34.9266	37.6101	41.0368
6 1/2	33.9652	34.3375	37.6017	38.4812	39.6243	42.7060	46.6523
6 3/4	38.2852	38.7083	42.4215	43.4233	44.7262	48.2437	52.7597
7	42.9574	43.4356	47.6372	48.7721	50.2490	54.2415	59.3796
7 1/4	47.9953	48.5333	53.2644	54.5437	55.2094	60.7180	66.5327
7 1/2	53.4130	54.0155	59.3188	60.7542	62.6243	67.6915	74.2398
7 3/4	59.2241	59.8961	65.8159	67.4197	69.5102	75.1804	82.5216
8	65.4425	66.1891	72.7715	74.5564	76.8838	83.2031	91.3987
8 1/4	72.0819	72.9086	80.2010	82.1803	84.7620	91.7780	100.8920
8 1/2	79.1562	80.0684	88.1206	90.3075	93.1614	100.9236	111.0220
8 3/4	86.6793	87.6827	96.5454	98.9542	102.0988	110.6583	121.8095
9	94.6648	95.7653	105.4913	108.1364	111.5907	121.0004	133.2753
9 1/4	103.1532	104.3572	115.0034	117.9006	121.6854	132.0023	145.4773
9 1/2	112.1074	113.4209	125.0408	128.2049	132.3396	143.6175	158.3649
9 3/4	121.5657	122.9950	135.6464	139.0932	143.5986	155.8956	171.9931
10	131.5418	133.0937	146.8357	150.5816	155.4794	168.8549	186.3824
10 1/4	142.0496	143.7308	158.6244	162.6863	167.9985	182.5139	201.5538
10 1/2	153.1028	154.9204	171.0282	175.4234	181.1728	196.8910	217.5278
10 3/4	164.7153	166.6764	184.0627	188.8089	195.0188	212.0046	234.3251
11	176.9010	179.0128	197.7436	202.8590	209.5535	227.8731	251.9666
11 1/4	189.6735	191.9438	212.0865	217.5898	224.7933	244.5149	270.4730
11 1/2	203.0467	205.4832	227.1071	233.0173	240.7551	261.9485	289.8648
11 3/4	217.0345	219.6450	242.8210	249.1578	257.4556	280.1922	310.1628
12	231.6505	234.4432	259.2438	266.0273	274.9116	299.2645	331.3878
12 1/4	246.9087	249.8919	276.3914	283.6419	293.1396	319.1838	353.5605
12 1/2	262.8229	266.0049	294.2792	302.0178	312.1565	339.9684	376.7016
12 3/4	279.4068	282.7964	312.9229	321.1710	331.9790	361.6368	400.8317
13	....	....	....	341.1177	352.6238	384.2075	425.9717
13 1/4	....	....	....	361.8339	374.1075	407.6988	452.1422
13 1/2	....	....	....	383.4559	396.4470	432.1291	479.3639
13 3/4	....	....	....	....	....	457.5169	507.6576

MOMENT OF INERTIA, I, (Continued)

Outside Diameter Inches	THICKNESS IN FRACTIONS OF AN INCH						
	5/8"	11/16"	3/4"	13/16"	7/8"	15/16"	1"
1 7/16	.2095	....	....	....	....	....	....
1 1/2	.2483	....	....	....	....	....	....
1 5/8	.3413	....	....	....	....	....	....
1 3/4	.4573	....	....	....	....	....	....
1 7/8	.5992	....	....	....	....	....	....
2	.7698	....	....	....	....	....	....
2 1/8	.9721	.9854	.9934	.9978	.9999	1.0007	1.0009
2 1/4	1.2089	1.2292	1.2425	1.2505	1.2549	1.2570	1.2578
2 3/8	1.4831	1.5127	1.5330	1.5462	1.5543	1.5587	1.5608
2 1/2	1.7976	1.8388	1.8683	1.8887	1.9019	1.9099	1.9144
2 5/8	2.1552	2.2108	2.2520	2.2816	2.3019	2.3151	2.3232
2 3/4	2.5588	2.6319	2.6875	2.7287	2.7582	2.7786	2.7918
2 7/8	3.0113	3.1051	3.1782	3.2338	3.2750	3.3045	3.3249
3	3.5156	3.6337	3.7275	3.8006	3.8562	3.8974	3.9269
3 1/8	4.0746	4.2209	4.3390	4.4328	4.5058	4.5614	4.6027
3 1/4	4.6911	4.8698	5.0161	5.1342	5.2279	5.3010	5.3566
3 3/8	5.3679	5.5835	5.7622	5.9085	6.0266	6.1204	6.1934
3 1/2	6.1081	6.3652	6.5807	6.7594	6.9057	7.0238	7.1176
3 5/8	6.9144	7.2181	7.4752	7.6908	7.8695	8.0158	8.1339
3 3/4	7.7897	8.1454	8.4491	8.7062	8.9218	9.1005	9.2468
3 7/8	8.7369	9.1502	9.5058	9.8096	10.0667	10.2822	10.4609
4	9.7589	10.2356	10.6488	11.0045	11.3083	11.5654	11.7809
4 1/8	10.8586	11.4049	11.8816	12.2948	12.6505	12.9542	13.2114
4 1/4	12.0388	12.6612	13.2075	13.6842	14.0974	14.4531	14.7568
4 3/8	13.3024	14.0077	14.6301	15.1764	15.6531	16.0663	16.4220
4 1/2	14.6523	15.4475	16.1528	16.7752	17.3215	17.7981	18.2114
4 5/8	16.0914	16.9838	17.7790	18.4842	19.1066	19.6529	20.1296
4 3/4	17.6225	18.6198	19.5122	20.3074	21.0126	21.6350	22.1813
4 7/8	19.2485	20.3586	21.3558	22.2482	23.0434	23.7487	24.3711
5	20.9723	22.2034	23.3134	24.3107	25.2031	25.9982	26.7035
5 1/8	22.7968	24.1573	25.3883	26.4983	27.4956	28.3880	29.1832
5 1/4	24.7248	26.2235	27.5840	28.8150	29.9250	30.9223	31.8147
5 3/8	26.7593	28.4053	29.9039	31.2644	32.4954	33.6055	34.6027
5 1/2	28.9030	30.7056	32.3516	33.8503	35.2108	36.4418	37.5518
5 3/4	33.5299	35.6750	37.6438	39.4464	41.0924	42.5911	43.9516
6	38.6285	41.1568	43.4883	45.6334	47.6023	49.4049	51.0508
6 1/4	44.2217	47.1766	49.9126	52.4410	54.7725	56.9175	58.8864
6 1/2	50.3327	53.7594	56.9444	59.8992	62.6353	65.1636	67.4951
6 3/4	56.9845	60.9308	64.6112	68.0379	71.2229	74.1777	76.9137
7	64.1999	68.7160	72.9407	76.8871	80.5675	83.9942	87.1791
7 1/4	72.0021	77.1402	81.9605	86.4766	90.7013	94.6477	98.3281
7 1/2	80.4141	86.2288	91.6983	96.8363	101.6567	106.1727	110.3975
7 3/4	89.4588	96.0072	102.1815	107.9962	113.4656	118.6037	123.4240
8	99.1593	106.5006	113.4378	119.9862	126.1605	131.9752	137.4446
8 1/4	109.5386	117.7343	125.4949	132.8362	139.7734	146.3218	152.4961
8 1/2	120.6197	129.7337	138.3804	146.5760	154.3366	161.6779	168.6151
8 3/4	132.4256	142.5240	152.1218	161.2357	169.8824	178.0781	185.8387
9	144.9794	156.1306	166.7467	176.8451	186.4429	195.5568	204.2035
9 1/4	158.3446	170.6227	182.3298	193.4839	204.1028	214.2037	223.8039
9 1/2	172.4666	185.9417	198.8090	211.0871	222.7941	233.9483	244.5671
9 3/4	187.4057	202.1531	216.2548	229.7299	242.5972	254.8752	266.5823
10	203.1848	219.2823	234.6949	249.4424	263.5441	277.0191	289.8864
10 1/4	219.8270	237.3546	254.1569	270.2544	285.6671	300.4145	314.5162
10 1/2	237.3553	256.3952	274.6685	292.1960	308.9984	325.0959	340.5085
10 3/4	255.7928	276.4295	296.2571	315.2970	333.5702	351.0978	367.9002
11	275.1623	297.4829	318.9505	339.5873	359.4149	378.4547	396.7280
11 1/4	295.4871	319.5806	342.7763	365.0968	386.5645	407.2012	427.0288
11 1/2	316.7899	342.7480	367.7621	391.8556	415.0513	437.3719	458.8395
11 3/4	339.0940	367.0103	393.9354	419.8935	444.9076	469.0011	492.1968
12	362.4223	392.3929	421.3240	449.2403	476.1655	502.1235	527.1376
12 1/4	386.7977	418.9211	449.9555	479.9261	508.8572	536.7735	563.6987
12 1/2	412.2434	446.6202	479.8574	511.9807	543.0151	572.9857	601.9169
12 3/4	438.7823	475.5155	511.0574	545.4341	578.6713	610.7946	641.8291
13	466.4375	505.6324	543.5830	580.3162	615.8580	650.2348	683.4720
13 1/4	495.2320	536.9962	577.4620	616.6569	654.6075	691.3407	726.8825
13 1/2	525.1888	569.6322	612.7220	654.4862	694.9520	734.1469	772.0975
13 3/4	556.3306	603.5656	649.3905	693.8339	736.9237	778.6879	819.1537
14	588.6812	638.8219	687.4951	734.7299	780.5548	824.9982	868.0880

SECTION MODULUS, S FOR NEUTRAL AXIS THROUGH CENTER OF SECTION

Outside Diameter Inches	THICKNESS IN GAGES							
	24 B.W.G.	23 B.W.G.	22 B.W.G.	21 B.W.G.	20 B.W.G.	19 B.W.G.	18 B.W.G.	17 B.W.G.
1/4	.0008	.0009	.0009	.0010	.0011	.0012	.0013	.0014
5/16	.0013	.0015	.0016	.0017	.0019	.0021	.0023	.0025
3/8	.0020	.0022	.0024	.0027	.0029	.0033	.0036	.0040
7/16	.0028	.0031	.0034	.0038	.0041	.0047	.0052	.0058
1/2	.0037	.0042	.0046	.0051	.0055	.0063	.0071	.0080
9/16	.0048	.0054	.0059	.0066	.0072	.0083	.0093	.0105
5/8	.0060	.0067	.0075	.0084	.0090	.0105	.0118	.0134
11/16	.0074	.0083	.0091	.0103	.0111	.0129	.0146	.0166
3/4	.0088	.0099	.0110	.0124	.0134	.0156	.0177	.0202
13/16	.0105	.0118	.0130	.0147	.0159	.0186	.0211	.0242
7/8	.0122	.0137	.0152	.0172	.0186	.0218	.0248	.0285
15/16	.0141	.0159	.0176	.0199	.0215	.0253	.0288	.0332
1	.0161	.0182	.0202	.0228	.0247	.0290	.0331	.0382
1 1/16	.0183	.0206	.0229	.0259	.0280	.0330	.0377	.0435
1 1/8	.0206	.0232	.0258	.0291	.0316	.0373	.0427	.0493
1 3/16	.0230	.0259	.0288	.0326	.0354	.0418	.0479	.0554
1 1/4	.0256	.0288	.0321	.0363	.0394	.0465	.0534	.0618
1 5/16	.0283	.0319	.0355	.0402	.0436	.0515	.0592	.0686
1 3/8	.0311	.0351	.0391	.0443	.0481	.0568	.0653	.0758
1 7/16	.0340	.0385	.0428	.0485	.0527	.0624	.0717	.0833
1 1/2	.0372	.0420	.0467	.0530	.0576	.0682	.0784	.0912
1 5/8	.0438	.0495	.0551	.0625	.0680	.0805	.0927	.1080
1 3/4	.0509	.0576	.0641	.0728	.0792	.0939	.1083	.1262
1 7/8	.0586	.0663	.0739	.0839	.0913	.1084	.1250	.1458
2	.0668	.0756	.0843	.0958	.1043	.1238	.1429	.1669
2 1/8	....	....	....	....	....	....	.1621	.1894
2 1/4	....	....	....	....	....	....	.1824	.2133
2 3/8	....	....	....	....	....	....	.2040	.2387
2 1/2	....	....	....	....	....	....	.2267	.2654
2 5/8	....	....	....	....	....	....	.2506	.2936
2 3/4	....	....	....	....	....	....	.2758	.3233
2 7/8	....	....	....	....	....	....	.3022	.3543
3	....	....	....	....	....	....	.3297	.3868
3 1/8	....	....	....	....	....	....	.3585	.4206
3 1/4	....	....	....	....	....	....	.3884	.4560

Outside Diameter Inches	THICKNESS IN GAGES							
	16 B.W.G.	15 B.W.G.	14 B.W.G.	13 B.W.G.	12 B.W.G.	11 B.W.G.	10 B.W.G.	9 B.W.G.
1/4	.0014	.0014	.0015	.0015	....	....	....	....
5/16	.0026	.0027	.0028	.0029	.0029	.0029	....	....
3/8	.0042	.0044	.0046	.0048	.0050	.0050	.0051	....
7/16	.0062	.0065	.0070	.0073	.0076	.0078	.0080	....
1/2	.0085	.0091	.0098	.0104	.0110	.0113	.0117	.0119
9/16	.0113	.0121	.0131	.0141	.0150	.0155	.0161	.0165
5/8	.0145	.0155	.0169	.0183	.0196	.0205	.0214	.0221
11/16	.0181	.0194	.0213	.0231	.0249	.0261	.0274	.0285
3/4	.0220	.0237	.0261	.0285	.0309	.0325	.0343	.0358
13/16	.0264	.0285	.0315	.0345	.0375	.0396	.0420	.0440
7/8	.0312	.0337	.0374	.0410	.0448	.0475	.0505	.0531
15/16	.0363	.0393	.0437	.0481	.0528	.0561	.0598	.0631
1	.0419	.0454	.0506	.0559	.0614	.0654	.0699	.0740
1 1/16	.0478	.0519	.0580	.0642	.0707	.0754	.0809	.0858
1 1/8	.0542	.0589	.0659	.0730	.0807	.0862	.0927	.0985
1 3/16	.0610	.0663	.0743	.0825	.0913	.0977	.1053	.1121
1 1/4	.0681	.0742	.0833	.0925	.1026	.1100	.1187	.1266
1 5/16	.0757	.0825	.0927	.1032	.1146	.1230	.1329	.1421
1 3/8	.0836	.0912	.1026	.1144	.1272	.1367	.1479	.1584
1 7/16	.0920	.1004	.1131	.1262	.1405	.1511	.1638	.1756
1 1/2	.1007	.1100	.1240	.1385	.1545	.1663	.1805	.1938
1 5/8	.1194	.1306	.1475	.1650	.1845	.1989	.2164	.2327
1 3/4	.1397	.1529	.1729	.1939	.2171	.2345	.2555	.2754
1 7/8	.1616	.1770	.2004	.2250	.2524	.2729	.2979	.3216
2	.1851	.2029	.2300	.2585	.2904	.3143	.3436	.3715
2 1/4	.2368	.2599	.2952	.3325	.3743	.4060	.4449	.4821
2 3/8	.2651	.2911	.3309	.3729	.4203	.4563	.5005	.5429
2 1/2	.2950	.3240	.3686	.4158	.4690	.5095	.5593	.6073
2 5/8	.3264	.3587	.4083	.4609	.5203	.5656	.6215	.6753
2 3/4	.3595	.3952	.4501	.5084	.5744	.6247	.6869	.7470
2 7/8	.3942	.4334	.4939	.5582	.6311	.6867	.7556	.8223
3	.4304	.4734	.5397	.6103	.6904	.7517	.8276	.9012
3 1/4	.5077	.5587	.6375	.7216	.8172	.8905	.9815	1.0699
3 3/8	.5487	.6040	.6895	.7807	.8846	.9643	1.0634	1.1598
3 1/2	.5913	.6511	.7435	.8422	.9547	1.0411	1.1485	1.2532
3 5/8	.6356	.6999	.7995	.9060	1.0274	1.1208	1.2370	1.3503
3 3/4	.6814	.7505	.8576	.9721	1.1029	1.2034	1.3287	1.4510
3 7/8	.7288	.8029	.9177	1.0406	1.1809	1.2890	1.4237	1.5554
4	.7778	.8570	.9798	1.1114	1.2617	1.3775	1.5220	1.6633
4 1/4	.8806	.9706	1.1102	1.2599	1.4313	1.5635	1.7285	1.8902
4 1/2	.9898	1.0913	1.2487	1.4178	1.6116	1.7611	1.9482	2.1316
4 3/4	1.1054	1.2190	1.3954	1.5851	1.8025	1.9706	2.1810	2.3875
5	1.2273	1.3538	1.5503	1.7616	2.0042	2.1919	2.4270	2.6579
5 1/4	1.3556	1.4956	1.7133	1.9475	2.2166	2.4249	2.6861	2.9429
5 1/2	1.4903	1.6445	1.8844	2.1427	2.4397	2.6697	2.9583	3.2424
5 3/4	....	....	....	....	....	....	3.2438	3.5564
6	....	....	....	....	....	....	3.5423	3.8850
6 1/4	....	....	....	....	....	....	3.8541	4.2280
6 1/2	....	....	....	....	....	....	4.1790	4.5856
6 3/4	....	....	....	....	....	....	4.5170	4.9578
7	....	....	....	....	....	....	4.8682	5.3445
7 1/4	....	....	....	....	....	....	5.2326	5.7457
7 1/2	....	....	....	....	....	....	5.6101	6.1614
7 3/4	....	....	....	....	....	....	6.0007	6.5917
8	....	....	....	....	....	....	6.4046	7.0365
8 1/4	....	....	....	....	....	....	6.8215	7.4958
8 1/2	....	....	....	....	....	....	7.2517	7.9696
8 3/4	....	....	....	....	....	....	7.6950	8.4580
9	....	....	....	....	....	....	8.1514	8.9609

SECTION MODULUS, S, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	5/32"	8 B.W.G.	7 B.W.G.	3/16"	6 B.W.G.	7/32"	5 B.W.G.	4 B.W.G.
5/8	.0224	.0227	.0231	.0233	....	....	....	....
11/16	.0290	.0295	.0302	.0305	.0310	.0313	.0313	.0316
3/4	.0366	.0373	.0383	.0388	.0395	.0401	.0402	.0406
13/16	.0451	.0461	.0475	.0482	.0493	.0502	.0503	.0511
7/8	.0545	.0558	.0578	.0587	.0603	.0616	.0617	.0629
15/16	.0649	.0666	.0692	.0704	.0725	.0743	.0744	.0761
1	.0762	.0783	.0817	.0831	.0859	.0883	.0885	.0907
1 1/16	.0885	.0911	.0952	.0971	.1005	.1036	.1038	.1068
1 1/8	.1017	.1049	.1098	.1121	.1164	.1202	.1205	.1243
1 3/16	.1159	.1197	.1256	.1283	.1335	.1382	.1385	.1432
1 1/4	.1310	.1354	.1424	.1457	.1518	.1575	.1579	.1635
1 5/16	.1471	.1522	.1604	.1641	.1714	.1781	.1786	.1853
1 3/8	.1642	.1700	.1794	.1838	.1922	.2000	.2006	.2085
1 7/16	.1822	.1888	.1995	.2045	.2143	.2233	.2240	.2332
1 1/2	.2011	.2086	.2207	.2265	.2375	.2479	.2487	.2593
1 5/8	.2419	.2513	.2665	.2737	.2878	.3011	.3021	.3159
1 3/4	.2866	.2980	.3167	.3256	.3431	.3596	.3609	.3783
1 7/8	.3350	.3488	.3713	.3820	.4033	.4238	.4251	.4465
2	.3873	.4035	.4303	.4431	.4684	.4928	.4946	.5206
2 1/8	.4434	.4624	.4937	.5087	.5386	.5674	.5696	.6004
2 1/4	.5034	.5253	.5615	.5789	.6137	.6473	.6499	.6861
2 3/8	.5671	.5922	.6337	.6538	.6938	.7326	.7356	.7776
2 1/2	.6347	.6632	.7103	.7332	.7789	.8233	.8268	.8749
2 5/8	.7062	.7382	.7914	.8172	.8689	.9194	.9233	.9781
2 3/4	.7815	.8173	.8769	.9058	.9640	1.0208	1.0252	1.0871
2 7/8	.8606	.9004	.9667	.9990	1.0640	1 1275	1.1325	1.2019
3	.9435	.9875	1.0610	1.0969	1.1690	1.2396	1.2451	1.3226
3 1/8	1.0303	1.0788	1.1598	1.1993	1.2789	1.3571	1.3632	1.4491
3 1/4	1.1209	1.1740	1.2629	1.3063	1.3939	1.4800	1.4867	1.5814
3 3/8	1.2154	1.2733	1.3704	1.4179	1.5138	1.6082	1.6156	1.7196
3 1/2	1.3136	1.3767	1.4824	1.5341	1.6387	1.7418	1.7499	1.8636
3 5/8	1.4157	1.4841	1.5988	1.6550	1.7686	1.8808	1.8895	2.0134
3 3/4	1.5217	1.5956	1.7196	1.7804	1.9035	2.0251	2.0346	2.1691
3 7/8	1.6315	1.7111	1.8448	1.9104	2.0433	2.1748	2.1851	2.3306
4	1.7451	1.8306	1.9744	2.0450	2.1882	2.3298	2.3409	2.4980
4 1/8	1.8626	1.9542	2.1085	2.1843	2.3380	2.4903	2.5022	2.6712
4 1/4	1.9838	2.0819	2.2470	2.3281	2.4928	2.6561	2.6688	2.8502
4 3/8	2.1090	2.2136	2.3898	2.4765	2.6525	2.8272	2.8409	3.0351
4 1/2	2.2379	2.3494	2.5371	2.6295	2.8173	3.0037	3.0184	3.2258
4 5/8	2.3707	2.4892	2.6889	2.7872	2.9870	3.1856	3.2012	3.4224
4 3/4	2.5073	2.6330	2.8450	2.9494	3.1617	3.3729	3.3895	3.6248
4 7/8	2.6478	2.7809	3.0056	3.1162	3.3414	3.5655	3.5831	3.8330
5	2.7921	2.9329	3.1705	3.2877	3.5261	3.7635	3.7822	4.0471
5 1/4	3.0922	3.2489	3.5137	3.6443	3.9104	4.1756	4.1964	4.4928
5 1/2	3.4076	3.5812	3.8746	4.0194	4.3146	4.6092	4.6323	4.9618
5 3/4	3.7384	3.9296	4.2531	4.4129	4.7388	5.0642	5.0898	5.4542
6	4.0845	4.2942	4.6493	4.8248	5.1829	5.5408	5.5689	5.9700
6 1/4	4.4459	4.6751	5.0632	5.2551	5.6469	6.0388	6.0696	6.5091
6 1/2	4.8227	5.0721	5.4948	5.7038	6.1309	6.5582	6.5919	7.0716
6 3/4	5.2149	5.4854	5.9440	6.1709	6.6347	7.0992	7.1357	7.6574
7	5.6223	5.9148	6.4109	6.6564	7.1585	7.6616	7.7012	8.2666
7 1/4	6.0451	6.3604	6.9140	7.1603	7.7023	8.2455	8.2883	8.8992
7 1/2	6.4833	6.8223	7.3977	7.6826	8.2659	8.8508	8.8969	9.5552
7 3/4	6.9368	7.3003	7.9176	8.2234	8.8495	9.4777	9.5272	10.2345
8	7.4056	7.7945	8.4551	8.7825	9.4530	10.1260	10.1790	10.9371
8 1/4	7.8898	8.3050	9.0104	9.3601	10.0765	10.7958	10.8525	11.6632
8 1/2	8.3893	8.8316	9.5833	9.9560	10.7198	11.4870	11.5475	12.4126
8 3/4	8.9041	9.3744	10.1739	10.5704	11.3831	12.1998	12.2642	13.1853
9	9.4343	9.9335	10.7821	11.2032	12.0664	12.9340	13.0024	13.9815
9 1/4	....	....	....	....	12.7729	13 6932	13.7659	14.8048
9 1/2	....	....	....	....	....	....	14.5475	15.6479
9 3/4	....	....	....	....	....	....	15.3507	16.5144
10	....	....	....	....	....	....	16.1756	17.4042
10 1/4	....	....	....	....	....	....	....	18.3173
10 1/2	....	....	....	....	....	....	....	19.2539

SECTION MODULUS, S, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	1/4"	3 B.W.G.	9/32"	2 B.W.G.	1 B.W.G.	5/16"	0 B.W.G.	11/32"
11/16	.0317	....	....	....	....	....	....	....
3/4	.0409	.0410	.0412	.0412	.0413	.0413	....	....
13/16	.0515	.0517	.0521	.0522	.0524	.0525	.0526	.0526
7/8	.0635	.0639	.0646	.0647	.0651	.0653	.0656	.0656
15/16	.0770	.0776	.0788	.0789	.0795	.0798	.0804	.0804
1	.0920	.0928	.0945	.0947	.0956	.0962	.0971	.0972
1 1/16	.1085	.1096	.1119	.1122	.1135	.1143	.1157	.1159
1 1/8	.1264	.1279	.1310	.1313	.1331	.1343	.1363	.1365
1 3/16	.1459	.1477	.1517	.1522	.1545	.1561	.1589	.1592
1 1/4	.1668	.1691	.1742	.1747	.1777	.1797	.1834	.1838
1 5/16	.1893	.1921	.1983	.1989	.2026	.2052	.2100	.2105
1 3/8	.2133	.2167	.2240	.2249	.2294	.2326	.2385	.2392
1 7/16	.2388	.2428	.2516	.2525	.2580	.2618	.2691	.2700
1 1/2	.2658	.2704	.2807	.2819	.2883	.2929	.3017	.3028
1 5/8	.3244	.3305	.3442	.3458	.3545	.3608	.3730	.3746
1 3/4	.3891	.3969	.4145	.4166	.4280	.4362	.4526	.4546
1 7/8	.4599	.4695	.4917	.4943	.5087	.5193	.5403	.5430
2	.5368	.5486	.5757	.5789	.5968	.6099	.6363	.6397
2 1/8	.6199	.6339	.6666	.6705	.6921	.7081	.7406	.7447
2 1/4	.7090	.7256	.7644	.7690	.7948	.8140	.8531	.8581
2 3/8	.8042	.8236	.8690	.8744	.9048	.9275	.9739	.9799
2 1/2	.9056	.9279	.9805	.9868	1.0222	1.0486	1.1031	1.1101
2 5/8	1.0131	1.0386	1.0989	1.1061	1.1468	1.1773	1.2405	1.2487
2 3/4	1.1267	1.1557	1.2242	1.2324	1.2789	1.3137	1.3862	1.3957
2 7/8	1.2465	1.2790	1.3564	1.3657	1.4182	1.4578	1.5403	1.5510
3	1.3724	1.4088	1.4955	1.5059	1.5649	1.6095	1.7026	1.7148
3 1/8	1.5044	1.5449	1.6414	1.6530	1.7190	1.7688	1.8733	1.8870
3 1/4	1.6425	1.6873	1.7943	1.8071	1.8804	1.9358	2.0523	2.0676
3 3/8	1.7868	1.8361	1.9540	1.9682	2.0492	2.1105	2.2396	2.2566
3 1/2	1.9371	1.9912	2.1207	2.1362	2.2253	2.2928	2.4353	2.4541
3 5/8	2.0937	2.1527	2.2942	2.3113	2.4087	2.4828	2.6393	2.6600
3 3/4	2.2563	2.3205	2.4746	2.4932	2.5996	2.6804	2.8516	2.8742
3 7/8	2.4251	2.4947	2.6619	2.6821	2.7977	2.8857	3.0723	3.0970
4	2.6000	2.6752	2.8562	2.8780	3.0033	3.0987	3.3012	3.3281
4 1/8	2.7811	2.8621	3.0573	3.0809	3.2162	3.3193	3.5386	3.5677
4 1/4	2.9683	3.0554	3.2653	3.2907	3.4364	3.5476	3.7842	3.8156
4 3/8	3.1616	3.2550	3.4802	3.5075	3.6640	3.7835	4.0382	4.0721
4 1/2	3.3611	3.4609	3.7020	3.7313	3.8990	4.0272	4.3005	4.3369
4 5/8	3.5667	3.6732	3.9308	3.9620	4.1413	4.2784	4.5712	4.6102
4 3/4	3.7784	3.8919	4.1664	4.1997	4.3910	4.5374	4.8502	4.8919
4 7/8	3.9962	4.1169	4.4089	4.4444	4.6480	4.8040	5.1377	5.1820
5	4.2202	4.3483	4.6583	4.6960	4.9124	5.0783	5.4332	5.4806
5 1/8	4.4504	4.5860	4.9146	4.9546	5.1842	5.3602	5.7373	5.7876
5 1/4	4.6866	4.8301	5.1779	5.2202	5.4633	5.6498	6.0496	6.1030
5 1/2	5.1776	5.3373	5.7250	5.7722	6.0436	6.2520	6.6994	6.7592
5 3/4	5.6930	5.8700	6.2997	6.3521	6.6534	6.8849	7.3825	7.4491
6	6.2330	6.4281	6.9021	6.9599	7.2926	7.5485	8.0989	8.1727
6 1/4	6.7976	7.0116	7.5320	7.5955	7.9613	8.2427	8.8488	8.9301
6 1/2	7.3867	7.6205	8.1896	8.2591	8.6594	8.9676	9.6320	9.7212
6 3/4	8.0003	8.2548	8.8748	8.9505	9.3869	9.7232	10.1523	10.5460
7	8.6385	8.9146	9.5876	9.6698	10.1439	10.5094	11.2985	11.4046
7 1/4	9.3012	9.5998	10.3279	10.4169	10.9303	11.3263	12.1819	12.2969
7 1/2	9.9884	10.3104	11.0959	11.1920	11.7462	12.1739	13.0985	13.2229
7 3/4	10.7002	11.0965	11.8915	11.9949	12.5916	13.0522	14.0486	14.1827
8	11.4365	11.8080	12.7148	12.8257	13.4664	13.9611	15.0321	15.1762
8 1/4	12.1974	12.5949	13.5656	13.6844	14.3706	14.9008	16.0489	16.2035
8 1/2	12.9828	13.4072	14.4440	14.5709	15.3043	15.8711	17.0991	17.2645
8 3/4	13.7928	14.2449	15.3500	15.4854	16.2674	16.8720	18.1826	18.3593
9	14.6273	15.1081	16.2837	16.4277	17.2600	17.9037	19.2996	19.4878
9 1/4	15.4904	16.0009	17.2494	17.4024	18.2868	18.9709	20.4552	20.6554
9 1/2	16.3742	16.9151	18.2385	18.4008	19.3386	20.0642	21.6392	21.8517
9 3/4	17.2826	17.8548	19.2553	19.4270	20.4198	21.1882	22.8566	23.0818
10	18.2155	18.8200	20.2997	20.4811	21.5304	22.3428	24.1073	24.3455
10 1/4	19.1730	19.8105	21.3716	21.5631	22.6706	23.5282	25.3915	25.6431
10 1/2	20.1550	20.8265	22.4712	22.6730	23.8402	24.7442	26.7090	26.9744
10 3/4	....	21.8680	23.5984	23.8108	25.0392	25.9909	28.0600	28.3394
11	....	22.9348	24.7533	24.9764	26.2677	27.2683	29.4443	29.7383
11 1/4	....	24.0271	25.9357	26.1700	27.5217	28.5764	30.8620	31.1709
11 1/2	....	25.1448	27.1458	27.3914	28.8131	29.9151	32.3131	32.6372
11 3/4	....	26.2880	28.3835	28.6407	30.1300	31.2846	33.7975	34.1373
12	....	27.4566	29.6488	29.9180	31.4764	32.6848	35.3154	35.6712

SECTION MODULUS, S, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH						
	3/8"	00 B.W.G.	000 B.W.G.	7/16"	0000 B.W.G.	1/2"	9/16"
13/16	.0526	....	....	....	....	....	....
7/8	.0657	....	....	....	....	....	....
15/16	.0807	.0807	.0808	.0808	....	....	....
1	.0977	.0978	.0981	.0981	.0981	....	....
1 1/16	.1168	.1169	.1175	.1176	.1177	....	....
1 1/8	.1380	.1382	.1392	.1394	.1395	.1397	....
1 3/16	.1613	.1616	.1633	.1636	.1638	.1642	....
1 1/4	.1868	.1872	.1897	.1901	.1906	.1914	....
1 5/16	.2144	.2150	.2185	.2192	.2199	.2212	....
1 3/8	.2443	.2450	.2497	.2507	.2518	.2538	.2549
1 7/16	.2763	.2772	.2834	.2847	.2862	.2891	.2909
1 1/2	.3106	.3117	.3196	.3213	.3233	.3272	.3300
1 5/8	.3858	.3874	.3994	.4021	.4053	.4120	.4174
1 3/4	.4700	.4722	.4893	.4932	.4979	.5084	.5175
1 7/8	.5632	.5662	.5893	.5947	.6013	.6164	.6305
2	.6655	.6693	.6995	.7067	.7155	.7363	.7566
2 1/8	.7769	.7816	.8199	.8292	.8407	.8680	.8958
2 1/4	.8973	.9032	.9506	.9623	.9767	1.0117	1.0483
2 3/8	1.0269	1.0339	1.0916	1.1059	1.1237	1.1674	1.2142
2 1/2	1.1656	1.1740	1.2429	1.2601	1.2817	1.3351	1.3936
2 5/8	1.3135	1.3233	1.4045	1.4250	1.4507	1.5149	1.5864
2 3/4	1.4705	1.4818	1.5764	1.6004	1.6307	1.7069	1.7927
2 7/8	1.6366	1.6497	1.7587	1.7866	1.8218	1.9109	2.0127
3	1.8120	1.8268	1.9514	1.9834	2.0239	2.1271	2.2462
3 1/8	1.9965	2.0132	2.1545	2.1909	2.2371	2.3554	2.4934
3 1/4	2.1901	2.2089	2.3679	2.4090	2.4613	2.5959	2.7541
3 3/8	2.3930	2.4139	2.5917	2.6378	2.6967	2.8486	3.0286
3 1/2	2.6050	2.6282	2.8259	2.8774	2.9431	3.1135	3.3167
3 5/8	2.8262	2.8518	3.0705	3.1276	3.2006	3.3906	3.6186
3 3/4	3.0566	3.0847	3.3255	3.3885	3.4692	3.6799	3.9341
3 7/8	3.2961	3.3269	3.5909	3.6601	3.7489	3.9814	4.2633
4	3.5449	3.5784	3.8667	3.9425	4.0398	4.2951	4.6063
4 1/8	3.8028	3.8393	4.1529	4.2355	4.3417	4.6210	4.9630
4 1/4	4.0700	4.1094	4.4495	4.5393	4.6548	4.9592	5.3334
4 3/8	4.3463	4.3889	4.7565	4.8537	4.9789	5.3096	5.7176
4 1/2	4.6318	4.6776	5.0739	5.1789	5.3142	5.6723	6.1155
4 5/8	4.9265	4.9757	5.4018	5.5148	5.6606	6.0472	6.5272
4 3/4	5.2304	5.2831	5.6400	5.8614	6.0182	6.4343	6.9526
4 7/8	5.5435	5.5999	6.0887	6.2188	6.3868	6.8336	7.3918
5	5.8658	5.9259	6.4478	6.5869	6.7666	7.2452	7.8447
5 1/8	6.1973	6.2613	6.8173	6.9656	7.1575	7.6691	8.3114
5 1/4	6.5380	6.6059	7.1972	7.3552	7.5595	8.1052	8.7919
5 3/8	6.8879	6.9599	7.5876	7.7554	7.9727	8.5536	9.2862
5 1/2	7.2470	7.3232	7.9883	8.1664	8.3970	9.0142	9.7942
5 3/4	7.9927	8.0778	8.8211	9.0205	9.2790	9.9722	10.8516
6	8.7753	8.8697	9.6956	9.9175	10.2055	10.9792	11.9641
6 1/4	9.5946	9.6989	10.6118	10.8575	11.1765	12.0352	13.1317
6 1/2	10.4508	10.5653	11.5697	11.8403	12.1921	13.1403	14.3545
6 3/4	11.3437	11.4691	12.5693	12.8661	13.2522	14.2944	15.6325
7	12.2735	12.4101	13.6106	13.9348	14.3568	15.4975	16.9656
7 1/4	13.2401	13.3885	14.6936	15.0465	15.2302	16.7498	18.3538
7 1/2	14.2434	14.4041	15.8183	16.2011	16.6998	18.0510	19.7972
7 3/4	15.2836	15.4570	16.9847	17.3986	17.9381	19.4013	21.2959
8	16.3606	16.5472	18.1928	18.6391	19.2209	20.8007	22.8496
8 1/4	17.4744	17.6748	19.4426	19.9225	20.5483	22.2492	24.4586
8 1/2	18.6250	18.8396	20.7342	21.2488	21.9203	23.7467	26.1228
8 3/4	19.8124	20.0417	22.0675	22.6181	23.3368	25.2933	27.8421
9	21.0366	21.2811	23.4425	24.0303	24.7979	26.8889	29.6167
9 1/4	20.3034	22.5637	24.8656	25.4920	26.3104	28.5410	31.4546
9 1/2	23.6016	23.8781	26.3244	26.9905	27.8610	30.2353	33.3400
9 3/4	24.9366	25.2297	27.8249	28.5319	29.4561	31.9786	35.2806
10	26.3084	26.6187	29.3671	30.1163	31.0959	33.7710	37.2765
10 1/4	27.7170	28.0450	30.9511	31.7437	32.7801	35.6125	39.3276
10 1/2	29.1625	29.5086	32.5768	33.4140	34.5091	37.5030	41.4339
10 3/4	30.6447	31.0096	34.2442	35.1272	36.2826	39.4427	43.5954
11	32.1638	32.5479	35.9534	36.8835	38.1006	41.4315	45.8121
11 1/4	33.7197	34.1233	37.7043	38.6826	39.8565	43.4693	48.0841
11 1/2	35.3125	35.7362	39.4969	40.5247	41.8705	45.5563	50.4113
11 3/4	36.9420	37.3864	41.3312	42.4098	43.8222	47.6923	52.7937
12	38.6084	39.0739	43.2073	44.3379	45.8186	49.8774	55.2313
12 1/4	40.3116	40.7987	45.1251	46.3089	47.8595	52.1116	57.7242
12 1/2	42.0516	42.5608	47.0847	48.3228	49.9450	54.3949	60.2723
12 3/4	43.8285	44.3602	49.0859	50.3798	52.0751	56.7273	62.8756
13	....	....	....	52.4796	54.2498	59.1088	65.5341
13 1/4	....	....	....	54.6164	56.4690	61.5394	68.2479
13 1/2	....	....	....	56.8083	58.7329	64.0191	71.0169
13 3/4	....	....	....	....	....	66.5479	73.8411

SECTION MODULUS, S, (Continued)

Outside Diameter Inches	THICKNESS IN FRACTIONS OF AN INCH						
	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
1 7/16	.2915	....	....	....	....	....	....
1 1/2	.3310	....	....	....	....	....	....
1 5/8	.4200	....	....	....	....	....	....
1 3/4	.5226	....	....	....	....	....	....
1 7/8	.6391	....	....	....	....	....	....
2	.7698	....	....	....	....	....	....
2 1/8	.9149	.9274	.9350	.9391	.9411	.9418	.9420
2 1/4	1.0746	1.0926	1.1044	1.1116	1.1155	1.1174	1.1181
2 3/8	1.2489	1.2738	1.2909	1.3021	1.3088	1.3126	1.3143
2 1/2	1.4381	1.4710	1.4947	1.5109	1.5215	1.5279	1.5315
2 5/8	1.6420	1.6844	1.7158	1.7383	1.7538	1.7639	1.7700
2 3/4	1.8609	1.9141	1.9545	1.9845	2.0060	2.0208	2.0304
2 7/8	2.0948	2.1601	2.2109	2.2496	2.2782	2.2988	2.3129
3	2.3437	2.4225	2.4850	2.5337	2.5708	2.5983	2.6179
3 1/8	2.6077	2.7014	2.7769	2.8370	2.8837	2.9193	2.9457
3 1/4	2.8868	2.9968	3.0868	3.1595	3.2172	3.2621	3.2964
3 3/8	3.1810	3.3087	3.4146	3.5013	3.5713	3.6269	3.6701
3 1/2	3.4903	3.6372	3.7604	3.8625	3.9461	4.0136	4.0672
3 5/8	3.8148	3.9824	4.1242	4.2432	4.3418	4.4225	4.4876
3 3/4	4.1545	4.3442	4.5062	4.6433	4.7583	4.8536	4.9316
3 7/8	4.5094	4.7226	4.9062	5.0630	5.1957	5.3069	5.3992
4	4.8794	5.1178	5.3244	5.5022	5.6541	5.7827	5.8904
4 1/8	5.2648	5.5296	5.7607	5.9611	6.1335	6.2808	6.4055
4 1/4	5.6653	5.9582	6.2153	6.4396	6.6341	6.8014	6.9444
4 3/8	6.0811	6.4035	6.6880	6.9378	7.1557	7.3446	7.5072
4 1/2	6.5121	6.8655	7.1790	7.4556	7.6984	7.9103	8.0939
4 5/8	6.9584	7.3443	7.6882	7.9932	8.2623	8.4985	8.7047
4 3/4	7.4200	7.8399	8.2156	8.5504	8.8474	9.1095	9.3395
4 7/8	7.8968	8.3522	8.7613	9.1275	9.4537	9.7430	9.9984
5	8.3889	8.8813	9.3253	9.7242	10.0812	10.3993	10.6814
5 1/8	8.8963	9.4272	9.9076	10.3408	10.7300	11.0782	11.3885
5 1/4	9.4190	9.9899	10.5082	10.9771	11.4000	11.7799	12.1199
5 3/8	9.9569	10.5694	11.1270	11.6332	12.0913	12.5043	12.8754
5 1/2	10.5102	11.1657	11.7642	12.3092	12.8039	13.2515	13.6552
5 3/4	11.6625	12.4086	13.0935	13.7205	14.2930	14.8143	15.2875
6	12.8761	13.7189	14.4961	15.2111	15.8674	16.4683	17.0169
6 1/4	14.1509	15.0965	15.9720	16.7811	17.5272	18.2136	18.8436
6 1/2	15.4870	16.5413	17.5213	18.4305	19.2724	20.0503	20.7677
6 3/4	16.8842	18.0535	19.1440	20.1594	21.1030	21.9785	22.7892
7	18.3428	19.6331	20.8402	21.9677	23.0192	23.9983	24.9083
7 1/4	19.8626	21.2800	22.6098	23.8556	25.0210	26.1097	27.1250
7 1/2	21.4437	22.9943	24.4528	25.8230	27.1084	28.3127	29.4393
7 3/4	23.0861	24.7760	26.3694	27.8700	29.2814	30.6074	31.8513
8	24.7898	26.6251	28.3594	29.9965	31.5401	32.9938	34.3611
8 1/4	26.5548	28.5416	30.4230	32.2027	33.8844	35.4719	36.9687
8 1/2	28.3811	30.5255	32.5601	34.4884	36.3145	38.0418	39.6741
8 3/4	30.2687	32.5769	34.7706	36.8538	38.8302	40.7035	42.4774
9	32.2176	34.6957	37.0548	39.2989	41.4317	43.4570	45.3785
9 1/4	34.2366	36.8914	39.4227	41.8344	44.1303	46.3143	48.3900
9 1/2	36.3088	39.1456	41.8545	44.4394	46.9040	49.2523	51.4878
9 3/4	38.4422	41.4673	44.3600	47.1241	49.7636	52.2821	54.6835
10	40.6370	43.8565	46.9390	49.8885	52.7088	55.4038	57.9773
10 1/4	42.8931	46.3131	49.5916	52.7326	55.7399	58.6175	61.3690
10 1/2	45.2105	48.8372	52.3178	55.6564	58.8568	61.9230	64.8588
10 3/4	47.5894	51.4287	55.1176	58.6599	62.0596	65.3205	68.4465
11	50.0295	54.0878	57.9910	61.7431	65.3482	68.8099	72.1324
11 1/4	52.5310	56.8143	60.9380	64.9061	68.7226	72.3913	75.9162
11 1/2	55.0939	59.6083	63.9586	68.1488	72.1828	76.0645	79.7982
11 3/4	57.7181	62.4698	67.0528	71.4712	75.7290	79.8300	83.7782
12	60.4037	65.3988	70.2207	74.8734	79.3609	83.6873	87.8563
12 1/4	63.1506	68.3953	73.4621	78.3553	83.0787	87.6365	92.0324
12 1/2	65.9589	71.4592	76.7772	81.9169	86.8824	91.6777	96.3067
12 3/4	68.8286	74.5907	80.1659	85.5583	90.7720	95.8109	100.6791
13	71.7596	77.7896	83.6282	89.2794	94.7474	100.0361	105.1495
13 1/4	74.7520	81.0560	87.1641	93.0803	98.8087	104.3533	109.7181
13 1/2	77.8057	84.3900	90.7736	96.9609	102.9559	108.7625	114.3848
13 3/4	80.9208	87.7914	94.4568	100.9213	107.1889	113.2637	119.1496
14	84.0973	91.2603	98.2136	104.9614	111.5078	117.8569	124.0126

RADIUS OF GYRATION, r FOR NEUTRAL AXIS THROUGH CENTER OF SECTION

Outside Diameter Inches	THICKNESS IN GAGES							
	24 B.W.G.	23 B.W.G.	22 B.W.G.	21 B.W.G.	20 B.W.G.	19 B.W.G.	18 B.W.G.	17 B.W.G.
1/4	.0809	.0800	.0791	.0779	.0770	.0750	.0731	.0709
5/16	.1030	.1020	.1010	.0998	.0988	.0967	.0947	.0922
3/8	.1250	.1240	.1230	.1217	.1208	.1186	.1165	.1139
7/16	.1471	.1461	.1451	.1438	.1428	.1406	.1384	.1357
1/2	.1691	.1681	.1671	.1658	.1648	.1626	.1603	.1576
9/16	.1912	.1902	.1892	.1879	.1869	.1846	.1823	.1795
5/8	2133	.2123	.2113	.2099	2089	.2066	.2043	.2015
11/16	2354	.2343	.2333	.2320	.2310	.2287	.2264	.2235
3/4	.2575	.2564	.2554	.2541	.2530	.2507	.2484	.2455
13/16	.2795	.2785	.2775	.2761	.2751	.2728	.2704	.2675
7/8	.3016	.3006	.2996	.2982	.2972	.2948	.2925	.2895
15/16	.3237	.3227	.3217	.3203	.3193	.3169	.3146	.3116
1	.3458	.3448	.3437	.3424	.3414	.3390	.3366	.3336
1 1/16	.3679	.3669	.3658	.3645	.3634	.3611	.3587	.3557
1 1/8	.3900	.3890	.3879	.3865	.3855	.3831	.3808	.3777
1 3/16	.4121	.4111	.4100	.4086	.4076	.4052	.4028	.3998
1 1/4	.4342	.4331	.4321	.4307	.4297	.4273	.4249	.4219
1 5/16	.4563	.4552	.4542	.4528	.4518	.4494	.4470	.4440
1 3/8	.4784	.4773	.4763	.4749	.4739	.4715	.4691	.4660
1 7/16	.5005	.4994	.4984	.4970	.4960	.4936	.4912	.4881
1 1/2	.5226	.5215	.5205	.5191	.5181	.5156	.5132	.5102
1 5/8	.5667	.5657	.5647	.5633	.5622	.5598	.5574	.5543
1 3/4	.6109	.6099	.6088	.6075	.6064	.6040	.6016	.5985
1 7/8	.6551	.6541	.6530	.6516	.6506	.6482	.6458	.6427
2	.6993	.6983	.6972	.6958	.6948	.6924	.6900	.6869
2 1/8	....	....	....	....	....	....	.7341	.7310
2 1/4	....	....	....	....	....	....	.7783	.7752
2 3/8	....	....	....	....	....	....	.8225	.8194
2 1/2	....	....	....	....	....	....	.8667	.8636
2 5/8	....	....	....	....	....	....	.9109	.9078
2 3/4	....	....	....	....	....	....	.9551	.9519
2 7/8	....	....	....	....	....	....	.9992	.9961
3	....	....	....	....	....	....	1.0434	1.0403
3 1/8	....	....	....	....	....	....	1.0876	1.0845
3 1/4	....	....	....	....	....	....	1.1318	1.1287
3 3/8	....	....	....	....	....	....	1.1760	1.1729

RADIUS OF GYRATION, r, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES							
	16 B.W.G.	15 B.W.G.	14 B.W.G.	13 B.W.G.	12 B.W.G.	11 B.W.G.	10 B.W.G.	9 B.W.G.
1/4	.0693	.0678	.0659	.0642	....	....	....	....
5/16	.0904	.0887	.0862	.0839	.0816	.0802	....	....
3/8	.1119	.1101	.1073	.1045	.1016	.0996	.0974	....
7/16	.1336	.1317	.1287	.1256	.1223	.1200	.1172	....
1/2	.1555	.1534	.1503	.1470	.1435	.1408	.1378	.1350
9/16	.1773	.1752	.1720	.1686	.1649	.1620	.1587	.1556
5/8	.1993	.1971	.1938	.1903	.1864	.1835	.1799	.1765
11/16	.2212	.2190	.2157	.2121	.2081	.2050	.2013	.1977
3/4	.2432	.2410	.2376	.2340	.2298	.2267	.2228	.2191
13/16	.2652	.2630	.2595	.2558	.2516	.2484	.2445	.2406
7/8	.2872	.2850	.2815	.2778	.2735	.2702	.2662	.2623
15/16	.3093	.3070	.3035	.2997	.2954	.2921	.2880	.2839
1	.3313	.3290	.3255	.3217	.3173	.3140	.3098	.3057
1 1/16	.3534	.3511	.3475	.3437	.3393	.3359	.3316	.3275
1 1/8	.3754	.3731	.3695	.3657	.3612	.3578	.3535	.3493
1 3/16	.3975	.3952	.3916	.3877	.3832	.3797	.3754	.3712
1 1/4	.4195	.4172	.4136	.4097	.4052	.4017	.3974	.3931
1 5/16	.4416	.4393	.4356	.4317	.4272	.4237	.4193	.4150
1 3/8	.4637	.4613	.4577	.4537	.4492	.4457	.4413	.4369
1 7/16	.4857	.4834	.4797	.4758	.4712	.4677	.4632	.4589
1 1/2	.5078	.5055	.5018	.4978	.4933	.4897	.4852	.4808
1 5/8	.5520	.5496	.5459	.5419	.5373	.5337	.5292	.5248
1 3/4	.5961	.5938	.5901	.5860	.5814	.5778	.5733	.5688
1 7/8	.6403	.6379	.6342	.6302	.6255	.6219	.6173	.6128
2	.6845	.6821	.6873	.6743	.6696	.6660	.6614	.6568
2 1/4	.7728	.7704	.7767	.7626	.7579	.7542	.7496	.7450
2 3/8	.8170	.8146	.8108	.8068	.8020	.7983	.7937	.7891
2 1/2	.8612	.8588	.8550	.8509	.8462	.8425	.8378	.8332
2 5/8	.9053	.9029	.8992	.8951	.8903	.8866	.8819	.8773
2 3/4	.9495	.9471	.9433	.9392	.9345	.9308	.9261	.9214
2 7/8	.9937	.9913	.9875	.9834	.9786	.9749	.9702	.9655
3	1.0379	1.0355	1.0317	1.0276	1.0228	1.0191	1.0143	1.0096
3 1/4	1.1263	1.1238	1.1200	1.1159	1.1111	1.1074	1.1026	1.0979
3 3/8	1.1704	1.1680	1.1642	1.1601	1.1553	1.1515	1.1468	1.1421
3 1/2	1.2146	1.2122	1.2084	1.2043	1.1995	1.1957	1.1910	1.1862
3 5/8	1.2588	1.2564	1.2526	1.2484	1.2436	1.2399	1.2351	1.2304
3 3/4	1.3030	1.3006	1.2968	1.2926	1.2878	1.2841	1.2793	1.2745
3 7/8	1.3472	1.3448	1.3409	1.3368	1.3320	1.3282	1.3234	1.3187
4	1.3914	1.3889	1.3851	1.3810	1.3762	1.3724	1.3676	1.3628
4 1/4	1.4797	1.4773	1.4735	1.4693	1.4645	1.4607	1.4559	1.4512
4 1/2	1.5681	1.5657	1.5619	1.5577	1.5529	1.5491	1.5443	1.5395
4 3/4	1.6565	1.6541	1.6502	1.6461	1.6412	1.6375	1.6326	1.6278
5	1.7449	1.7424	1.7386	1.7345	1.7296	1.7258	1.7210	1.7162
5 1/4	1.8333	1.8308	1.8270	1.8228	1.8180	1.8142	1.8093	1.8045
5 1/2	1.9217	1.9192	1.9154	1.9112	1.9063	1.9025	1.8977	1.8929
5 3/4	....	....	....	....	....	....	1.9861	1.9812
6	....	....	....	....	....	....	2.0744	2.0696
6 1/4	....	....	....	....	....	....	2.1628	2.1580
6 1/2	....	....	....	....	....	....	2.2512	2.2463
6 3/4	....	....	....	....	....	....	2.3395	2.3347
7	....	....	....	....	....	....	2.4279	2.4231
7 1/4	....	....	....	....	....	....	2.5163	2.5114
7 1/2	....	....	....	....	....	....	2.6047	2.5998
7 3/4	....	....	....	....	....	....	2.6930	2.6882
8	....	....	....	....	....	....	2.7814	2.7765
8 1/4	....	....	....	....	....	....	2.8698	2.8649
8 1/2	....	....	....	....	....	....	2.9582	2.9533
8 3/4	....	....	....	....	....	....	3.0465	3.0417
9	....	....	....	....	....	....	3.1349	3.1300

RADIUS OF GYRATION, r, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	5/32"	8 B.W.G.	7 B.W.G.	3/16"	6 B.W.G.	7/32"	5 B.W.G.	4 B.W.G.
5/8	.1746	.1727	.1697	.1682	....	....	....	....
11/16	.1957	.1937	.1903	.1887	.1857	.1828	.1826	.1798
3/4	.2170	.2148	.2113	.2096	.2062	.2031	.2028	.1996
13/16	.2385	.2362	.2325	.2307	.2271	.2237	.2234	.2198
7/8	.2600	.2577	.2538	.2519	.2481	.2445	.2442	.2404
15/16	.2816	.2792	.2752	.2733	.2694	.2656	.2653	.2612
1	.3033	.3009	.2968	.2948	.2907	.2868	.2865	.2822
1 1/16	.3251	.3226	.3184	.3163	.3122	.3081	.3078	.3034
1 1/8	.3469	.3443	.3401	.3380	.3337	.3296	.3292	.3246
1 3/16	.3687	.3661	.3618	.3597	.3553	.3511	.3507	.3460
1 1/4	.3906	.3880	.3836	.3814	.3770	.3727	.3723	.3675
1 5/16	.4125	.4098	.4054	.4032	.3987	.3943	.3940	.3891
1 3/8	.4344	.4317	.4272	.4250	.4205	.4160	.4156	.4107
1 7/16	.4563	.4536	.4491	.4468	.4423	.4377	.4374	.4323
1 1/2	.4782	.4755	.4710	.4687	.4641	.4595	.4591	.4540
1 5/8	.5222	.5194	.5148	.5125	.5078	.5031	.5027	.4975
1 3/4	.5661	.5634	.5587	.5563	.5516	.5468	.5465	.5411
1 7/8	.6101	.6073	.6026	.6002	.5954	.5908	.5902	.5848
2	.6542	.6513	.6466	.6442	.6393	.6344	.6341	.6286
2 1/8	.6982	.6954	.6906	.6882	.6833	.6783	.6779	.6724
2 1/4	.7423	.7394	.7346	.7322	.7272	.7223	.7219	.7163
2 3/8	.7863	.7835	.7786	.7762	.7712	.7662	.7658	.7602
2 1/2	.8304	.8276	.8227	.8202	.8152	.8102	.8098	.8041
2 5/8	.8745	.8716	.8667	.8643	.8593	.8542	.8538	.8481
2 3/4	.9186	.9157	.9108	.9084	.0933	.8982	.8978	.8921
2 7/8	.9628	.9599	.9549	.9524	.9474	.9423	.9419	.9361
3	1.0069	1.0040	.9990	.9965	.9914	.9863	.9859	.9801
3 1/8	1.0510	1.0481	1.0431	1.0406	1.0355	1.0304	1.0300	1.0241
3 1/4	1.0952	1.0922	1.0872	1.0847	1.0796	1.0744	1.0740	1.0682
3 3/8	1.1393	1.1364	1.1313	1.1288	1.1237	1.1185	1.1181	1.1122
3 1/2	1.1834	1.1805	1.1755	1.1730	1.1678	1.1626	1.1622	1.1563
3 5/8	1.2276	1.2246	1.2196	1.2171	1.2119	1.2067	1.2063	1.2004
3 3/4	1.2717	1.2688	1.2637	1.2612	1.2561	1.2508	1.2504	1.2445
3 7/8	1.3159	1.3129	1.3079	1.3054	1.3002	1.2949	1.2945	1.2886
4	1.3600	1.3571	1.3520	1.3495	1.3443	1.3391	1.3386	1.3327
4 1/8	1.4042	1.4012	1.3962	1.3936	1.3884	1.3832	1.3828	1.3768
4 1/4	1.4484	1.4454	1.4403	1.4378	1.4326	1.4273	1.4269	1.4209
4 3/8	1.4925	1.4896	1.4845	1.4819	1.4767	1.4714	1.4710	1.4650
4 1/2	1.5367	1.5337	1.5286	1.5261	1.5209	1.5156	1.5152	1.5091
4 5/8	1.5809	1.5779	1.5728	1.5702	1.5650	1.5597	1.5593	1.5533
4 3/4	1.6250	1.6220	1.6169	1.6144	1.6092	1.6039	1.6034	1.5974
4 7/8	1.6692	1.6662	1.6611	1.6586	1.6533	1.6480	1.6476	1.6415
5	1.7134	1.7104	1.7053	1.7027	1.6975	1.6921	1.6917	1.6857
5 1/4	1.8017	1.7987	1.7936	1.7910	1.7858	1.7804	1.7800	1.7740
5 1/2	1.8901	1.8871	1.8819	1.8794	1.8741	1.8688	1.8683	1.8623
5 3/4	1.9784	1.9754	1.9703	1.9677	1.9624	1.9571	1.9566	1.9506
6	2.0668	2.0638	2.0586	2.0560	2.0508	2.0454	2.0450	2.0389
6 1/4	2.1551	2.1521	2.1470	2.1444	2.1391	2.1337	2.1333	2.1272
6 1/2	2.2435	2.2405	2.2353	2.2327	2.2274	2.2221	2.2216	2.2155
6 3/4	2.3318	2.3288	2.3237	2.3211	2.3158	2.3104	2.3100	2.3038
7	2.4202	2.4172	2.4120	2.4094	2.4041	2.3987	2.3983	2.3922
7 1/4	2.5086	2.5056	2.5038	2.4978	2.4925	2.4871	2.4866	2.4805
7 1/2	2.5969	2.5939	2.5887	2.5862	2.5808	2.5754	2.5750	2.5688
7 3/4	2.6853	2.6823	2.6771	2.6745	2.6692	2.6638	2.6633	2.6572
8	2.7737	2.7707	2.7655	2.7629	2.7575	2.7521	2.7517	2.7455
8 1/4	2.8621	2.8590	2.8538	2.8512	2.8459	2.8405	2.8400	2.8339
8 1/2	2.9504	2.9474	2.9422	2.9396	2.9343	2.9288	2.9284	2.9222
8 3/4	3.0388	3.0358	3.0306	3.0280	3.0226	3.0172	3.0168	3.0106
9	3.1272	3.1241	3.1189	3.1163	3.1110	3.1056	3.1051	3.0989
9 1/4	....	....	....	....	3.1998	3.1944	3.1939	3.1877
9 1/2	....	....	....	....	....	....	3.2823	3.2761
9 3/4	....	....	....	....	....	....	3.3707	3.3645
10	....	....	....	....	....	....	3.4590	3.4528
10 1/4	....	....	....	....	....	....	....	3.5412
10 1/2	....	....	....	....	....	....	....	3.6296

RADIUS OF GYRATION, r, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH							
	1/4"	3 B.W.G.	9/32"	2 B.W.G.	1 B.W.G.	5/16"	0 B.W.G.	11/32"
11/16	.1781	....	....	....	....	....	....	....
3/4	.1976	.1962	.1932	.1929	.1912	.1900	....	....
13/16	.2176	.2160	.2125	.2121	.2099	.2084	.2058	.2055
7/8	.2379	.2362	.2322	.2318	.2292	.2275	.2241	.2237
15/16	.2586	.2567	.2524	.2519	.2491	.2470	.2430	.2425
1	.2795	.2775	.2728	.2723	.2692	.2670	.2624	.2619
1 1/16	.3005	.2984	.2935	.2929	.2897	.2872	.2823	.2816
1 1/8	.3217	.3195	.3144	.3138	.3103	.3077	.3024	.3017
1 3/16	.3430	.3408	.3354	.3348	.3312	.3284	.3228	.3221
1 1/4	.3644	.3621	.3566	.3559	.3522	.3493	.3434	.3426
1 5/16	.3859	.3835	.3779	.3772	.3733	.3704	.3642	.3634
1 3/8	.4074	.4050	.3992	.3985	.3945	.3915	.3851	.3843
1 7/16	.4290	.4266	.4207	.4200	.4159	.4128	.4062	.4053
1 1/2	.4506	.4482	.4422	.4414	.4373	.4341	.4273	.4264
1 5/8	.4941	.4915	.4853	.4846	.4803	.4770	.4699	.4690
1 3/4	.5376	.5350	.5287	.5279	.5235	.5201	.5127	.5118
1 7/8	.5812	.5786	.5721	.5713	.5668	.5633	.5558	.5548
2	.6250	.6223	.6157	.6149	.6103	.6067	.5990	.5980
2 1/8	.6687	.6660	.6594	.6585	.6538	.6502	.6424	.6413
2 1/4	.7126	.7098	.7031	.7023	.6975	.6938	.6859	.6848
2 3/8	.7564	.7537	.7469	.7460	.7412	.7375	.7294	.7283
2 1/2	.8003	.7975	.7907	.7898	.7850	.7812	.7730	.7719
2 5/8	.8443	.8415	.8345	.8337	.8288	.8250	.8167	.8156
2 3/4	.8882	.8854	.8784	.8776	.8726	.8688	.8605	.8593
2 7/8	.9322	.9294	.9224	.9215	.9165	.9126	.9042	.9031
3	.9762	.9734	.9663	.9654	.9604	.9565	.9481	.9469
3 1/8	1.0203	1.0174	1.0103	1.0094	1.0044	1.0004	.9919	.9908
3 1/4	1.0643	1.0614	1.0543	1.0534	1.0483	1.0444	1.0358	1.0346
3 3/8	1.1083	1.1054	1.0983	1.0974	1.0923	1.0883	1.0797	1.0785
3 1/2	1.1524	1.1495	1.1423	1.1414	1.1363	1.1323	1.1236	1.1225
3 5/8	1.1965	1.1935	1.1863	1.1854	1.1803	1.1763	1.1676	1.1664
3 3/4	1.2405	1.2376	1.2304	1.2295	1.2243	1.2203	1.2115	1.2104
3 7/8	1.2846	1.2817	1.2744	1.2735	1.2683	1.2643	1.2555	1.2543
4	1.3287	1.3258	1.3185	1.3176	1.3124	1.3084	1.2995	1.2983
4 1/8	1.3728	1.3699	1.3626	1.3617	1.3564	1.3524	1.3435	1.3423
4 1/4	1.4169	1.4140	1.4066	1.4057	1.4005	1.3964	1.3876	1.3864
4 3/8	1.4610	1.4581	1.4507	1.4498	1.4446	1.4405	1.4316	1.4304
4 1/2	1.5051	1.5022	1.4948	1.4939	1.4887	1.4846	1.4756	1.4744
4 5/8	1.5493	1.5463	1.5389	1.5380	1.5327	1.5286	1.5197	1.5185
4 3/4	1.5934	1.5904	1.5830	1.5821	1.5768	1.5727	1.5637	1.5625
4 7/8	1.6375	1.6345	1.6271	1.6262	1.6209	1.6168	1.6078	1.6066
5	1.6817	1.6786	1.6712	1.6703	1.6650	1.6609	1.6519	1.6507
5 1/8	1.7258	1.7228	1.7154	1.7144	1.7091	1.7050	1.6960	1.6947
5 1/4	1.7699	1.7669	1.7595	1.7586	1.7533	1.7491	1.7401	1.7388
5 3/8	1.8141	1.8110	1.8036	1.8027	1.7974	1.7932	1.7841	1.7829
5 1/2	1.8582	1.8552	1.8477	1.8468	1.8415	1.8373	1.8282	1.8270
5 3/4	1.9465	1.9435	1.9360	1.9351	1.9297	1.9256	1.9164	1.9152
6	2.0348	2.0318	2.0243	2.0234	2.0180	2.0138	2.0047	2.0034
6 1/4	2.1231	2.1201	2.1126	2.1116	2.1063	2.1021	2.0929	2.0917
6 1/2	2.2114	2.2084	2.2009	2.1999	2.1945	2.1904	2.1812	2.1799
6 3/4	2.2997	2.2967	2.2892	2.2882	2.2828	2.2786	2.2694	2.2682
7	2.3881	2.3850	2.3775	2.3765	2.3711	2.3669	2.3577	2.3564
7 1/4	2.4764	2.4733	2.4658	2.4648	2.4594	2.4552	2.4460	2.4447
7 1/2	2.5647	2.5617	2.5541	2.5532	2.5477	2.5435	2.5342	2.5330
7 3/4	2.6531	2.6500	2.6424	2.6415	2.6361	2.6318	2.6225	2.6213
8	2.7414	2.7383	2.7308	2.7298	2.7244	2.7201	2.7108	2.7096
8 1/4	2.8298	2.8267	2.8191	2.8181	2.8127	2.8085	2.7991	2.7979
8 1/2	2.9181	2.9150	2.9074	2.9065	2.9010	2.8968	2.8874	2.8862
8 3/4	3.0065	3.0034	2.9958	2.9948	2.9894	2.9851	2.9758	2.9745
9	3.0948	3.0917	3.0841	3.0832	3.0777	3.0734	3.0641	3.0628
9 1/4	3.1836	3.1805	3.1729	3.1720	3.1665	3.1622	3.1529	3.1516
9 1/2	3.2720	3.2689	3.2612	3.2603	3.2548	3.2506	3.2412	3.2399
9 3/4	3.3603	3.3572	3.3496	3.3487	3.3432	3.3389	3.3295	3.3283
10	3.4487	3.4456	3.4380	3.4370	3.4315	3.4273	3.4179	3.4166
10 1/4	3.5371	3.5340	3.5263	3.5254	3.5199	3.5156	3.5062	3.5049
10 1/2	3.6254	3.6224	3.6147	3.6137	3.6083	3.6040	3.5946	3.5933
10 3/4	....	3.7107	3.7031	3.7021	3.6966	3.6923	3.6829	3.6816
11	....	3.7991	3.7914	3.7905	3.7850	3.7807	3.7713	3.7700
11 1/4	....	3.8875	3.8798	3.8789	3.8733	3.8691	3.8596	3.8583
11 1/2	....	3.9759	3.9682	3.9672	3.9617	3.9574	3.9481	3.9467
11 3/4	....	4.0643	4.0565	4.0556	4.0501	4.0458	4.0363	4.0351
12	....	4.1526	4.1449	4.1440	4.1385	4.1342	4.1247	4.1234

RADIUS OF GYRATION, r, (Continued)

Outside Diameter Inches	THICKNESS IN GAGES AND FRACTIONS OF AN INCH						
	3/8″	00 B.W.G.	000 B.W.G.	7/16″	0000 B.W.G.	1/2″	9/16″
13/16	.2037	....	....	....	....	....	....
7/8	.2209	....	....	....	....	....	....
15/16	.2390	.2385	.2353	.2348	....	....	....
1	.2576	.2570	.2527	.2519	.2510	....	....
1 1/16	.2768	.2761	.2708	.2697	.2684	....	....
1 1/8	.2964	.2956	2895	.2881	.2864	.2829	....
1 3/16	.3163	.3155	.3086	.3069	.3049	.3005	....
1 1/4	.3365	.3356	.3281	.3262	.3239	.3186	....
1 5/16	.3569	.3560	.3479	.3458	.3433	.3372	....
1 3/8	.3775	.3765	.3679	.3657	.3630	.3563	.3493
1 7/16	.3983	.3972	.3882	.3859	.3829	.3756	.3677
1 1/2	.4192	.4181	.4086	.4062	.4031	.3952	.3865
1 5/8	.4614	.4602	.4500	.4474	.4440	.4352	.4250
1 3/4	.5038	.5026	.4919	.4891	.4855	.4759	.4645
1 7/8	.5466	.5453	.5342	.5312	.5274	.5172	.5048
2	.5896	.5883	.5767	.5736	.5696	.5590	.5451
2 1/8	.6327	.6314	.6195	.6163	.6122	.6011	.5871
2 1/4	.6760	.6746	.6625	.6592	.6549	.6434	.6288
2 3/8	.7194	.7180	.7056	.7022	.6978	.6860	.6709
2 1/2	.7629	.7614	.7488	.7454	.7409	.7288	.7132
2 5/8	.8064	.8050	.7921	.7887	.7841	.7718	.7558
2 3/4	.8500	.8486	.8356	.8320	.8274	.8149	.7985
2 7/8	.8937	.8922	.8791	.8755	.8708	.8580	.8414
3	.9375	.9360	.9227	.9190	.9143	.9013	.8844
3 1/8	.9812	.9797	.9663	.9626	.9578	.9447	.9275
3 1/4	1.0250	1.0235	1.0100	1.0063	1.0014	.9882	.9707
3 3/8	1.0689	1.0673	1.0537	1.0500	1.0451	1.0317	1.0140
3 1/2	1.1127	1.1112	1.0975	1.0937	1.0888	1.0752	1.0574
3 5/8	1.1566	1.1551	1.1413	1.1375	1.1325	1.1189	1.1008
3 3/4	1.2005	1.1990	1.1851	1.1813	1.1763	1.1625	1.1443
3 7/8	1.2445	1.2429	1.2289	1.2251	1.2201	1.2062	1.1879
4	1.2884	1.2868	1.2728	1.2689	1.2639	1.2500	1.2315
4 1/8	1.3324	1.3308	1.3167	1.3128	1.3077	1.2937	1.2751
4 1/4	1.3764	1.3748	1.3606	1.3567	1.3516	1.3375	1.3188
4 3/8	1.4204	1.4188	1.4045	1.4006	1.3955	1.3813	1.3625
4 1/2	1.4644	1.4628	1.4485	1.4446	1.4394	1.4252	1.4062
4 5/8	1.5084	1.5068	1.4925	1.4885	1.4833	1.4690	1.4500
4 3/4	1.5524	1.5508	1.5364	1.5325	1.5273	1.5129	1.4938
4 7/8	1.5965	1.5948	1.5804	1.5765	1.5712	1.5568	1.5376
5	1.6405	1.6389	1.6244	1.6204	1.6152	1.6007	1.5814
5 1/8	1.6846	1.6829	1.6684	1.6644	1.6592	1.6447	1.6253
5 1/4	1.7286	1.7270	1.7125	1.7084	1.7032	1.6886	1.6691
5 3/8	1.7727	1.7711	1.7565	1.7525	1.7472	1.7326	1.7130
5 1/2	1.8168	1.8151	1.8005	1.7965	1.7912	1.7765	1.7569
5 3/4	1.9049	1.9033	1.8886	1.8846	1.8792	1.8645	1.8448
6	1.9931	1.9915	1.9767	1.9727	1.9673	1.9525	1.9327
6 1/4	2.0813	2.0797	2.0649	2.0608	2.0554	2.0406	2.0206
6 1/2	2.1695	2.1679	2.1530	2.1489	2.1436	2.1286	2.1086
6 3/4	2.2577	2.2561	2.2412	2.2371	2.2311	2.2167	2.1966
7	2.3460	2.3443	2.3294	2.3253	2.3199	2.3048	2.2846
7 1/4	2.4342	2.4326	2.4176	2.4135	2.4081	2.3930	2.3727
7 1/2	2.5225	2.5208	2.5058	2.5017	2.4963	2.4811	2.4608
7 3/4	2.6108	2.6091	2.5941	2.5899	2.5845	2.5693	2.5489
8	2.6991	2.6974	2.6823	2.6782	2.6727	2.6575	2.6370
8 1/4	2.7873	2.7857	2.7706	2.7664	2.7609	2.7457	2.7252
8 1/2	2.8756	2.8739	2.8588	2.8547	2.8492	2.8339	2.8133
8 3/4	2.9639	2.9622	2.9471	2.9429	2.9374	2.9221	2.9015
9	3.0522	3.0505	3.0354	3.0312	3.0257	3.0103	2.9897
9 1/4	3.1410	3.1393	3.1241	3.1199	3.1144	3.0990	3.0783
9 1/2	3.2293	3.2276	3.2124	3.2082	3.2027	3.1873	3.1665
9 3/4	3.3176	3.3159	3.3007	3.2965	3.2910	3.2756	3.2548
10	3.4060	3.4043	3.3890	3.3848	3.3793	3.3638	3.3430
10 1/4	3.4943	3.4926	3.4774	3.4731	3.4676	3.4521	3.4313
10 1/2	3.5826	3.5809	3.5657	3.5614	3.5559	3.5404	3.5195
10 3/4	3.6701	3.6693	3.6540	3.6498	3.6442	3.6287	3.6078
11	3.7593	3.7576	3.7423	3.7381	3.7325	3.7170	3.6960
11 1/4	3.8477	3.8459	3.8307	3.8264	3.8208	3.8053	3.7843
11 1/2	3.9360	3.9343	3.9190	3.9147	3.9091	3.8936	3.8726
11 3/4	4.0244	4.0227	4.0073	4.0031	3.9975	3.9819	3.9609
12	4.1127	4.1110	4.0957	4.0914	4.0858	4.0702	4.0492
12 1/4	4.2011	4.1994	4.1840	4.1797	4.1741	4.1585	4.1375
12 1/2	4.2894	4.2877	4.2723	4.2681	4.2625	4.2469	4.2258
12 3/4	4.3778	4.3761	4.3607	4.3564	4.3508	4.3352	4.3141
13	....	....	....	4.4448	4.4392	4.4235	4.4024
13 1/4	....	....	....	4.5329	4.5275	4.5118	4.4907
13 1/2	....	....	....	4.6215	4.6159	4.6002	4.5790
13 3/4	....	....	....	....	....	4.6885	4.6673

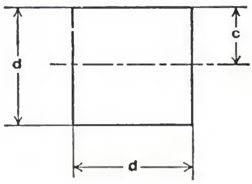
RADIUS OF GYRATION, r, (Continued)

Outside Diameter Inches	THICKNESS IN FRACTIONS OF AN INCH						
	5/8″	11/16″	3/4″	13/16″	7/8″	15/16″	1″
1 7/16	.3624	....	....	....	....	....	....
1 1/2	.3801	....	....	....	....	....	....
1 5/8	.4169	....	....	....	....	....	....
1 3/4	.4550	....	....	....	....	....	....
1 7/8	.4941	....	....	....	....	....	....
2	.5340	....	....	....	....	....	....
2 1/8	.5745	.5633	.5537	.5457	.5394	.5349	.5321
2 1/4	.6155	.6036	.5929	.5837	.5762	.5702	.5659
2 3/8	.6569	.6442	.6327	.6226	.6139	.6067	.6011
2 1/2	.6987	.6853	.6731	.6621	.6525	.6442	.6373
2 5/8	.7408	.7268	.7139	.7022	.6917	.6825	.6745
2 3/4	.7831	.7686	.7551	.7428	.7315	.7214	.7126
2 7/8	.8256	.8106	.7967	.7837	.7718	.7609	.7513
3	.8682	.8529	.8385	.8250	.8125	.8010	.7905
3 1/8	.9110	.8954	.8805	.8665	.8535	.8414	.8303
3 1/4	.9540	.9380	.9228	.9084	.8948	.8822	.8705
3 3/8	.9970	.9807	.9652	.9504	.9364	.9233	.9110
3 1/2	1.0402	1.0236	1.0077	.9926	.9782	.9647	.9519
3 5/8	1.0834	1.0666	1.0504	1.0350	1.0203	1.0063	.9931
3 3/4	1.1267	1.1097	1.0933	1.0775	1.0625	1.0481	1.0345
3 7/8	1.1701	1.1528	1.1362	1.1202	1.1048	1.0901	1.0761
4	1.2135	1.1961	1.1792	1.1629	1.1473	1.1323	1.1180
4 1/8	1.2570	1.2394	1.2223	1.2058	1.1899	1.1746	1.1600
4 1/4	1.3005	1.2827	1.2655	1.2488	1.2326	1.2171	1.2022
4 3/8	1.3441	1.3261	1.3087	1.2918	1.2755	1.2597	1.2445
4 1/2	1.3877	1.3696	1.3520	1.3350	1.3184	1.3024	1.2869
4 5/8	1.4313	1.4131	1.3954	1.3781	1.3614	1.3452	1.3295
4 3/4	1.4750	1.4567	1.4388	1.4214	1.4045	1.3880	1.3721
4 7/8	1.5187	1.5003	1.4823	1.4647	1.4476	1.4310	1.4149
5	1.5625	1.5439	1.5258	1.5081	1.4908	1.4740	1.4577
5 1/8	1.6062	1.5876	1.5693	1.5515	1.5341	1.5171	1.5006
5 1/4	1.6500	1.6312	1.6129	1.5949	1.5774	1.5603	1.5436
5 3/8	1.6938	1.6750	1.6565	1.6384	1.6207	1.6035	1.5866
5 1/2	1.7376	1.7187	1.7001	1.6819	1.6641	1.6467	1.6298
5 3/4	1.8253	1.8062	1.7875	1.7691	1.7511	1.7334	1.7161
6	1.9131	1.8939	1.8750	1.8564	1.8381	1.8202	1.8027
6 1/4	2.0009	1.9816	1.9625	1.9437	1.9253	1.9072	1.8895
6 1/2	2.0888	2.0693	2.0501	2.0312	2.0126	1.9943	1.9764
6 3/4	2.1767	2.1571	2.1378	2.1187	2.1000	2.0815	2.0634
7	2.2647	2.2450	2.2255	2.2063	2.1875	2.1688	2.1505
7 1/4	2.3526	2.3328	2.3133	2.2940	2.2750	2.2562	2.2378
7 1/2	2.4407	2.4208	2.4011	2.3817	2.3626	2.3437	2.3251
7 3/4	2.5287	2.5087	2.4890	2.4695	2.4502	2.4312	2.4125
8	2.6168	2.5967	2.5769	2.5573	2.5379	2.5188	2.5000
8 1/4	2.7048	2.6847	2.6648	2.6451	2.6257	2.6065	2.5875
8 1/2	2.7929	2.7728	2.7528	2.7330	2.7135	2.6942	2.6751
8 3/4	2.8811	2.8608	2.8408	2.8209	2.8013	2.7819	2.7627
9	2.9692	2.9489	2.9288	2.9089	2.8892	2.8697	2.8504
9 1/4	3.0578	3.0374	3.0173	2.9973	2.9775	2.9579	2.9385
9 1/2	3.1459	3.1256	3.1053	3.0853	3.0654	3.0458	3.0263
9 3/4	3.2341	3.2137	3.1934	3.1733	3.1534	3.1337	3.1141
10	3.3223	3.3018	3.2815	3.2614	3.2414	3.2216	3.2020
10 1/4	3.4105	3.3900	3.3698	3.3494	3.3294	3.3095	3.2898
10 1/2	3.4988	3.4782	3.4578	3.4375	3.4175	3.3975	3.3777
10 3/4	3.5870	3.5664	3.5459	3.5256	3.5055	3.4855	3.4657
11	3.6752	3.6546	3.6341	3.6137	3.5935	3.5735	3.5536
11 1/4	3.7635	3.7428	3.7222	3.7018	3.6816	3.6615	3.6416
11 1/2	3.8517	3.8310	3.8104	3.7900	3.7698	3.7496	3.7296
11 3/4	3.9400	3.9192	3.8986	3.8781	3.8578	3.8376	3.8176
12	4.0282	4.0075	3.9868	3.9663	3.9459	3.9257	3.9056
12 1/4	4.1165	4.0957	4.0750	4.0545	4.0341	4.0138	3.9937
12 1/2	4.2048	4.1840	4.1632	4.1427	4.1222	4.1019	4.0817
12 3/4	4.2931	4.2722	4.2515	4.2308	4.2104	4.1900	4.1698
13	4.3814	4.3605	4.3397	4.3191	4.2985	4.2781	4.2579
13 1/4	4.4697	4.4488	4.4280	4.4073	4.3867	4.3663	4.3460
13 1/2	4.5579	4.5370	4.5162	4.4955	4.4749	4.4544	4.4340
13 3/4	4.6463	4.6253	4.6044	4.5837	4.5631	4.5426	4.5222
14	4.7345	4.7136	4.6927	4.6719	4.6513	4.6308	4.6104

PROPERTIES OF SECTIONS

SQUARE

Axis of moments through center



$A = d^2$

$c = \frac{d}{2}$

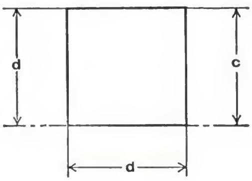
$I = \frac{d^4}{12}$

$S = \frac{d^3}{6}$

$r = \frac{d}{\sqrt{12}} = .288675\,d$

SQUARE

Axis of moments on base



$A = d^2$

$c = d$

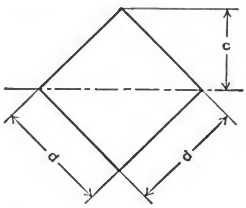
$I = \frac{d^4}{3}$

$S = \frac{d^3}{3}$

$r = \frac{d}{\sqrt{3}} = .577350\,d$

SQUARE

Axis of moments on diagonal



$A = d^2$

$c = \frac{d}{\sqrt{2}} = .707107\,d$

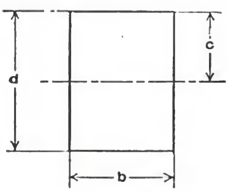
$I = \frac{d^4}{12}$

$S = \frac{d^3}{6\sqrt{2}} = .117851\,d^3$

$r = \frac{d}{\sqrt{12}} = .288675\,d$

RECTANGLE

Axis of moments through center



$A = bd$

$c = \frac{d}{2}$

$I = \frac{bd^3}{12}$

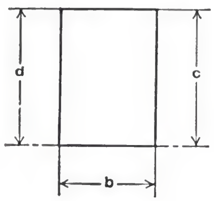
$S = \frac{bd^2}{6}$

$r = \frac{d}{\sqrt{12}} = .288675\,d$

PROPERTIES OF SECTIONS

RECTANGLE

Axis of moments on base



$$A = bd$$

$$c = d$$

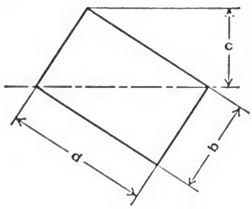
$$I = \frac{bd^3}{3}$$

$$S = \frac{bd^2}{3}$$

$$r = \frac{d}{\sqrt{3}} = .577350\ d$$

RECTANGLE

Axis of moments on diagonal



$$A = bd$$

$$c = \frac{bd}{\sqrt{b^2 + d^2}}$$

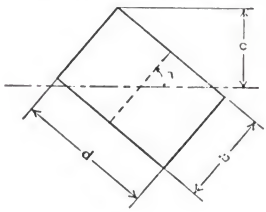
$$I = \frac{b^3d^3}{6\,(b^2 + d^2)}$$

$$S = \frac{b^2d^2}{6\sqrt{b^2 + d^2}}$$

$$r = \frac{bd}{\sqrt{6\,(b^2 + d^2)}}$$

RECTANGLE

Axis of moments any line through center of gravity



$$A = bd$$

$$c = \frac{b \sin a + d \cos a}{2}$$

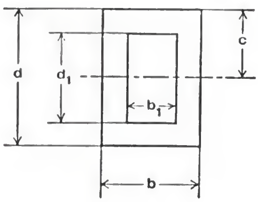
$$I = \frac{bd\,(b^2 \sin^2 a + d^2 \cos^2 a)}{12}$$

$$S = \frac{bd\,(b^2 \sin^2 a + d^2 \cos^2 a)}{6\,(b \sin a + d \cos a)}$$

$$r = \sqrt{\frac{b^2 \sin^2 a + d^2 \cos^2 a}{12}}$$

HOLLOW RECTANGLE

Axis of moments through center



$$A = bd - b_1d_1$$

$$c = \frac{d}{2}$$

$$I = \frac{bd^3 \quad b_1d_1^3}{12}$$

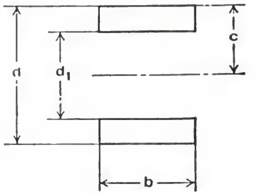
$$S = \frac{bd^3 - b_1d_1^3}{6d}$$

$$r = \sqrt{\frac{bd^3 - b_1d_1^3}{12\,A}}$$

PROPERTIES OF SECTIONS

EQUAL RECTANGLES

Axis of moments through center of gravity



$$A = b(d - d_1)$$

$$c = \frac{d}{2}$$

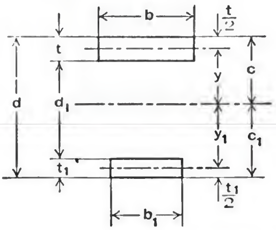
$$I = \frac{b(d^3 - d_1^3)}{12}$$

$$S = \frac{b(d^3 - d_1^3)}{6d}$$

$$r = \sqrt{\frac{d^3 - d_1^3}{12(d - d_1)}}$$

UNEQUAL RECTANGLES

Axis of moments through center of gravity



$$A = bt + b_1t_1$$

$$c = \frac{\frac{1}{2}bt^2 + b_1t_1(d - \frac{1}{2}t_1)}{A}$$

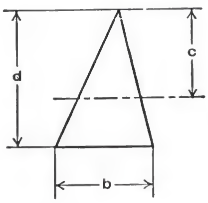
$$I = \frac{bt^3}{12} + bty^2 + \frac{b_1t_1^3}{12} + b_1t_1y_1^2$$

$$S = \frac{I}{c} \qquad S_1 = \frac{I}{c_1}$$

$$r = \sqrt{\frac{I}{A}}$$

TRIANGLE

Axis of moments through center of gravity



$$A = \frac{bd}{2}$$

$$c = \frac{2d}{3}$$

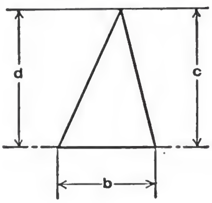
$$I = \frac{bd^3}{36}$$

$$S = \frac{bd^2}{24}$$

$$r = \frac{d}{\sqrt{18}} = .235702\ d$$

TRIANGLE

Axis of moments on base



$$A = \frac{bd}{2}$$

$$c = d$$

$$I = \frac{bd^3}{12}$$

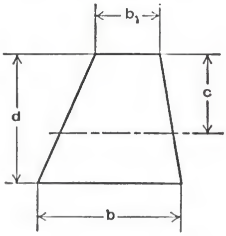
$$S = \frac{bd^2}{12}$$

$$r = \frac{d}{\sqrt{6}} = .408248\ d$$

PROPERTIES OF SECTIONS

TRAPEZOID

Axis of moments through center of gravity



$$A = \frac{d(b + b_1)}{2}$$

$$c = \frac{d(2b + b_1)}{3(b + b_1)}$$

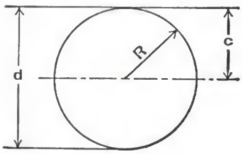
$$I = \frac{d^3\,(b^2 + 4\,bb_1 + b_1^2)}{36\,(b + b_1)}$$

$$S = \frac{d^2\,(b^2 + 4\,bb_1 + b_1^2)}{12\,(2b + b_1)}$$

$$r = \frac{d}{6(b + b_1)}\sqrt{2\,(b^2 + 4\,bb_1 + b_1^2)}$$

CIRCLE

Axis of moments through center



$$A = \frac{\pi d^2}{4} = \pi R^2 = .785398\,d^2 = 3.141593\,R^2$$

$$c = \frac{d}{2} = R$$

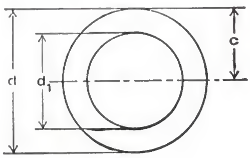
$$I = \frac{\pi d^4}{64} = \frac{\pi R^4}{4} = .049087\,d^4 = .785398\,R^4$$

$$S = \frac{\pi d^3}{32} = \frac{\pi R^3}{4} = .098175\,d^3 = .785398\,R^3$$

$$r = \frac{d}{4} = \frac{R}{2}$$

HOLLOW CIRCLE

Axis of moments through center



$$A = \frac{\pi(d^2 - d_1^2)}{4} = .785398\,(d^2 - d_1^2)$$

$$c = \frac{d}{2}$$

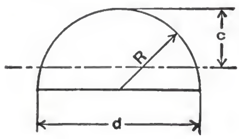
$$I = \frac{\pi(d^4 - d_1^4)}{64} = .049087\,(d^4 - d_1^4)$$

$$S = \frac{\pi(d^4 - d_1^4)}{32d} = .098175\,\frac{d^4 - d_1^4}{d}$$

$$r = \frac{\sqrt{d^2 + d_1^2}}{4}$$

HALF CIRCLE

Axis of moments through center of gravity



$$A = \frac{\pi R^2}{2} = 1.570796\,R^2$$

$$c = R\left(1 - \frac{4}{3\pi}\right) = .575587\,R$$

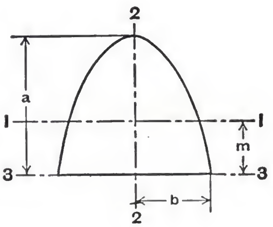
$$I = R^4\left(\frac{\pi}{8} - \frac{8}{9\pi}\right) = .109757\,R^4$$

$$S = \frac{R^3}{24}\,\frac{(9\pi^2 - 64)}{(3\pi - 4)} = .190687\,R^3$$

$$r = R\,\frac{\sqrt{9\pi^2 - 64}}{6\pi} = .264336\,R$$

PROPERTIES OF SECTIONS

PARABOLA



$$A = \frac{4}{3}ab$$

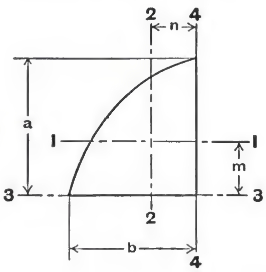
$$m = \frac{2}{5}a$$

$$I_1 = \frac{16}{175}a^3b$$

$$I_2 = \frac{4}{15}ab^3$$

$$I_3 = \frac{32}{105}a^3b$$

HALF PARABOLA



$$A = \frac{2}{3}ab$$

$$m = \frac{2}{5}a$$

$$n = \frac{3}{8}b$$

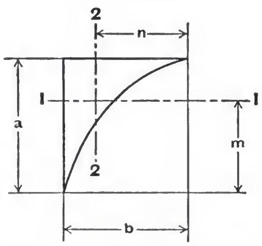
$$I_1 = \frac{8}{175}a^3b$$

$$I_2 = \frac{19}{480}ab^3$$

$$I_3 = \frac{16}{105}a^3b$$

$$I_4 = \frac{2}{15}ab^3$$

COMPLEMENT OF HALF PARABOLA



$$A = \frac{1}{3}ab$$

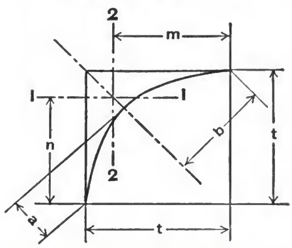
$$m = \frac{7}{10}a$$

$$n = \frac{3}{4}b$$

$$I_1 = \frac{37}{2100}a^3b$$

$$I_2 = \frac{1}{80}ab^3$$

PARABOLIC FILLET IN RIGHT ANGLE



$$a = \frac{t}{2\sqrt{2}}$$

$$b = \frac{t}{\sqrt{2}}$$

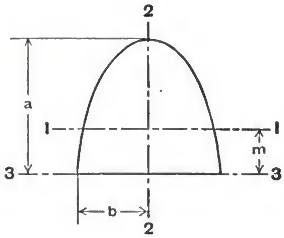
$$A = \frac{1}{6}t^2$$

$$m = n = \frac{4}{5}t$$

$$I_1 = I_2 = \frac{11}{2100}t^4$$

PROPERTIES OF SECTIONS

* HALF ELLIPSE



$$A = \frac{1}{2}\pi ab$$

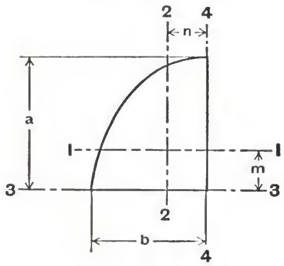
$$m = \frac{4a}{3\pi}$$

$$I_1 = a^3b\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)$$

$$I_2 = \frac{1}{8}\pi ab^3$$

$$I_3 = \frac{1}{8}\pi a^3b$$

* QUARTER ELLIPSE



$$A = \frac{1}{4}\pi ab$$

$$m = \frac{4a}{3\pi}$$

$$n = \frac{4b}{3\pi}$$

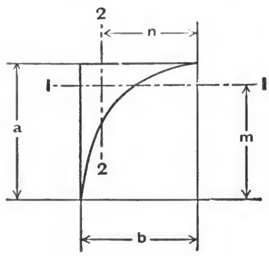
$$I_1 = a^3b\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_2 = ab^3\left(\frac{\pi}{16} - \frac{4}{9\pi}\right)$$

$$I_3 = \frac{1}{16}\pi a^3b$$

$$I_4 = \frac{1}{16}\pi ab^3$$

* ELLIPTIC COMPLEMENT



$$A = ab\left(1 - \frac{\pi}{4}\right)$$

$$m = \frac{a}{6\left(1 - \frac{\pi}{4}\right)}$$

$$n = \frac{b}{6\left(1 - \frac{\pi}{4}\right)}$$

$$I_1 = a^3b\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

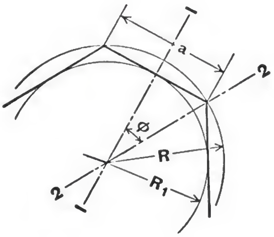
$$I_2 = ab^3\left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{36\left(1 - \frac{\pi}{4}\right)}\right)$$

* To obtain properties of half circle, quarter circle and circular complement substitute a = b = R.

PROPERTIES OF SECTIONS

REGULAR POLYGON

Axis of moments through center



n = Number of sides

$$\phi = \frac{180^\circ}{n}$$

$$a = 2\sqrt{R^2 - R_1^2}$$

$$R = \frac{a}{2\sin\phi}$$

$$R_1 = \frac{a}{2\tan\phi}$$

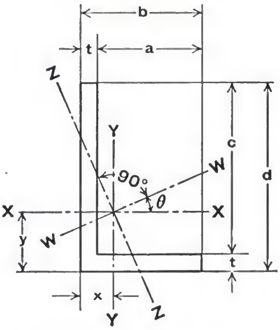
$$A = \frac{1}{4}na^2\cot\phi = \frac{1}{2}nR^2\sin 2\phi = nR_1^2\tan\phi$$

$$I_1 = I_2 = \frac{A(6R^2 - a^2)}{24} = \frac{A(12R_1^2 + a^2)}{48}$$

$$r_1 = r_2 = \sqrt{\frac{6R^2 - a^2}{24}} = \sqrt{\frac{12R_1^2 + a^2}{48}}$$

ANGLE

Axis of moments through center of gravity



Z-Z is axis of minimum I

$$\tan 2\theta = \frac{2K}{I_Y - I_X}$$

$$A = t(b + c) \quad x = \frac{b^2 + ct}{2(b + c)} \quad y = \frac{d^2 + at}{2(b + c)}$$

K = Product of Inertia about X-X & Y-Y

$$= \mp \frac{abcdt}{4(b + c)}$$

$$I_X = \frac{1}{3}\left(t(d - y)^3 + by^3 - a(y - t)^3\right)$$

$$I_Y = \frac{1}{3}\left(t(b - x)^3 + dx^3 - c(x - t)^3\right)$$

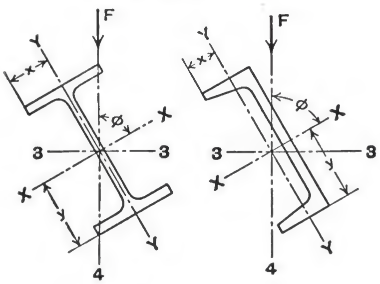
$$I_Z = I_X\sin^2\theta + I_Y\cos^2\theta + K\sin 2\theta$$

$$I_W = I_X\cos^2\theta + I_Y\sin^2\theta - K\sin 2\theta$$

K is negative when heel of angle, with respect to c. g., is in 1st or 3rd quadrant, positive when in 2nd or 4th quadrant.

BEAMS AND CHANNELS

Transverse force oblique through center of gravity



$$I_3 = I_X\sin^2\phi + I_Y\cos^2\phi$$

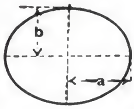
$$I_4 = I_X\cos^2\phi + I_Y\sin^2\phi$$

$$f = M\left(\frac{y}{I_X}\sin\phi + \frac{x}{I_Y}\cos\phi\right)$$

where M is bending moment due to force F.

MENSURATION OF PLANE FIGURES

ELLIPSE



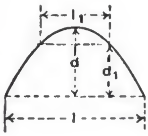
$U = \left(\frac{a-b}{a+b}\right)^2$ Ellipticity $= e = \frac{\sqrt{a^2-b^2}}{a}$ Area $= \pi ab$

$$\text{Perimeter} = s = \pi(a+b)\left[1 + \frac{1}{4}U + \frac{1}{64}U^2 + \frac{1}{256}U^3 + \frac{1}{512}U^4 + \frac{1}{1024}U^5 + \dots\right]$$

$$= 4a\left[\int_0^{\frac{\pi}{2}} (1 - \sin^2\theta \sin^2\phi)^{1/2} d\phi\right] \quad \text{where} \quad \theta = \sin^{-1} e$$

Values of [. . .] (elliptic integrals) for various values of θ are found in Smithsonian Physical Tables and save calculating series.

PARABOLA



Length of arc (s)

Area $= \frac{2}{3} ld$ $= \frac{1}{2}\sqrt{16d^2+l^2} + .28782314\frac{l^2}{d}\log_{10}\left(\frac{4d+\sqrt{16d^2+l^2}}{l}\right)$

Height of segment $d_1 = \frac{d}{l_1}(l^2 - l_1^2)$ $= l\left[1 + \frac{2}{3}V - \frac{2}{5}V^2 + \dots\dots\right]$

Width of " $l_1 = l\sqrt{\frac{d-d_1}{d}}$ $V = \left(\frac{2d}{l}\right)^2$

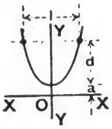
CYCLOID

r = Radius of Generating Circle

Area $= 3\pi r^2$

Arc Length (s) = 8r

CATENARY



From table of hyperbolic functions find a solution of equation,

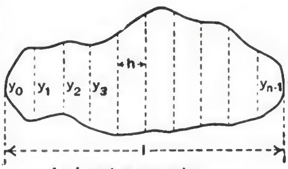
$$\cosh x = \frac{2 \times d}{l} + 1$$

$x = \frac{l}{2a}$ or $a = \frac{l}{2x}$

Length of Curve $= 2a \sinh x = \frac{l}{x}\sinh x$

Plot curve $y = a\cosh x$ where $x < \frac{l}{2a}$

AREA BY APPROXIMATION



A_t least accurate,
A_s most "

Divide l into n equal parts, by parallel lines.

Then $h = \frac{l}{n}$. n preferably 10 or greater.

Measure y_0, y_1, y_2 . . . . y_{n-1} and y_n.

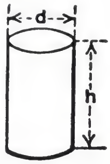
Area, by Trapezoidal Rule (Boundary replaced by line segments)
$A_t = h\,[\frac{1}{2}(y_0 + y_n) + y_1 + y_2 + \dots\dots y_{n-1}]$ n even or odd

Area, by Durand's Rule
$A_d = h\,[0.4(y_0 + y_n) + 1.1(y_1 + y_{n-1}) + y_2 + y_3 + \dots y_{n-2}]$
n even or odd

Area, by Simpson's Rule (Boundary replaced by 2d degree curves)

$$A_s = \frac{h}{3}\,[(y_0 + y_n) + 4(y_1 + y_3 + \dots y_{n-1}) + 2(y_2 + y_4 + \dots y_{n-2})]$$
n even.

SURFACES AND VOLUMES OF SOLIDS



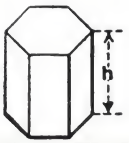
CYLINDER

Convex Surface $= \pi dh$

Total Surface $= \pi dh + \frac{\pi d^2}{2}$

Volume $= \frac{\pi}{4} d^2 h$

Volume Cylinder, right or oblique = area of section at right angles to sides × length of side.

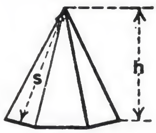


PRISM

Lateral Surface = h × Base Perimeter

Total Surface = Lateral Surface + (2 × Base Area)

Volume = h × Base Area



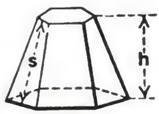
PYRAMID

Lateral Surface $= \frac{s}{2} \times$ Base Perimeter

Total Surface = Lateral Surface + Base Area

Volume $= \frac{h}{3} \times$ Base Area

Center of Gravity $= \frac{h}{4}$, above base



FRUSTUM OF PYRAMID

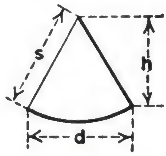
Lateral Surface = s(Top + Base Perimeters) ÷ 2

If a = top area and A = base area,

Total Surface = Lateral Surface + (a + A)

Volume $= h(a + A + \sqrt{aA}) \div 3$

Center of Gravity above base $= \frac{h}{4}\left(\frac{3a + A + 2\sqrt{aA}}{a + A + \sqrt{aA}}\right)$



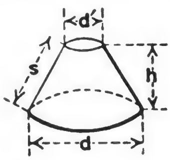
CONE

Convex Surface $= \frac{\pi}{2} ds = \frac{\pi d}{4}\sqrt{d^2 + 4h^2}$

Total Surface $=$ Convex Surface $+ \frac{\pi d^2}{4}$

Volume $= \frac{\pi}{12} d^2 h = \frac{\pi}{24} d^2 \sqrt{4s^2 - d^2}$

Center of Gravity above base $= \frac{h}{4}$



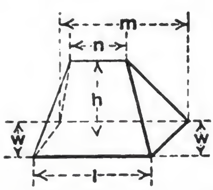
FRUSTUM OF CONE

Convex Surface $= \frac{\pi s}{2}(d + d') = \frac{\pi}{4}(d + d')\sqrt{4h^2 + (d - d')^2}$

Total Surface $= \frac{\pi s}{2}(d + d') + \frac{\pi}{4}(d^2 + d'^2)$

Volume $= \frac{\pi h}{12}(d^2 + dd' + d'^2)$

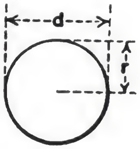
Center of Gravity above base $= \frac{h(d^2 + 2dd' + 3d'^2)}{4(d^2 + dd' + d'^2)}$



WEDGE

Surface = Sum of surfaces of bounding planes

Volume $= \frac{wh}{6}(l + m + n)$



SPHERE

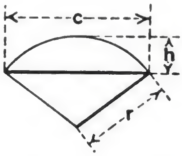
Surface $= \pi d^2 = 4\pi r^2$

Volume $= \dfrac{\pi d^3}{6} = \dfrac{4}{3}\pi r^3$

Side of an equal cube = diameter of sphere $\times$ 0.806

Length of an equal cylinder = diameter of sphere $\times$ 0.6667

Center of Gravity of Half Sphere = $\frac{3}{8}r$ above spherical center

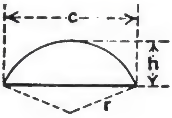


SPHERICAL SECTOR

Total Surface $= \dfrac{\pi r}{2}(4h + c)$

Volume $= \frac{2}{3}\pi r^2 h = \frac{2}{3}\pi r^2\left(r - \sqrt{r^2 - \dfrac{c^2}{4}}\right)$

Center of Gravity above center of sphere $= \frac{3}{4}\left(r - \dfrac{h}{2}\right)$



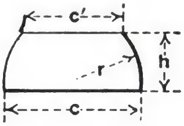
SPHERICAL SEGMENT

Spherical Surface $= 2\pi rh = \pi(c^2 + 4h^2) \div 4$

Total Surface = Spherical Surface $+ (\pi c^2 \div 4)$

Volume $= \pi h^2(3r - h) \div 3 = \pi h(3c^2 + 4h^2) \div 24$

Center of gravity above base of segment
$= h(4r - h) \div 4(3r - h)$

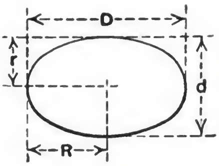


SPHERICAL ZONE

Convex Surface $= 2\pi rh$

Total Surface $= 2\pi rh + \dfrac{\pi}{4}(c^2 + c'^2)$

Volume $= \dfrac{\pi h}{24}(3c^2 + 3c'^2 + 4h^2)$



ELLIPSOID (I. Revolution about transverse axis)

Surface $= 2\pi r\left[r + R\left(\dfrac{\sin^{-1}e}{e}\right)\right]$

Volume $= \dfrac{4}{3}\pi R r^2$

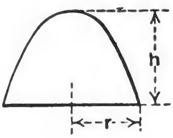
$\sin^{-1}e$ = Angle, in radians, whose sine = e

ELLIPSOID (II. Revolution about conjugate axis)

Surface $= \pi\left[2R^2 + \dfrac{2.303r^2}{e}\log.\left(\dfrac{1+e}{1-e}\right)\right]$

Volume $= \dfrac{4}{3}\pi R^2 r$ Where $e = \dfrac{\sqrt{R^2 - r^2}}{R}$

Use common, or base 10, log.

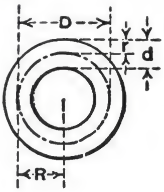


PARABOLOID

Convex Surface $= \dfrac{\pi r}{6h^2}\left[(r^2 + 4h^2)^{3/2} - r^3\right]$

Total Surface = Convex Surface $+ \pi r^2$

Volume $= \dfrac{\pi r^2 h}{2}$ Center of Gravity $= \dfrac{h}{3}$ above base



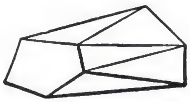
CIRCULAR RING (TORUS)

D and R = Mean Diameter and Mean Radius, respectively, of Ring

d and r = Mean Diameter and Mean Radius, respectively, of Section

Surface $= \pi^2 Dd = 4\pi^2 Rr$

Volume $= 2\pi^2 Rr^2 = \frac{\pi^2}{4} Dd^2$



PRISMOID

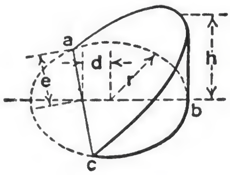
End faces are in parallel planes.

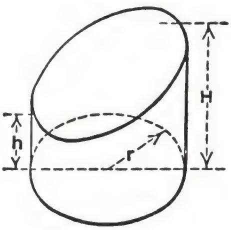
Volume $= \frac{l}{6}(A + A' + 4M)$, where

l = perpendicular distance between ends

A,A′ = areas of ends

M = area of mid section, parallel to ends





UNGULAS FROM RIGHT CIRCULAR CYLINDER

(As formed by cutting plane oblique to base)

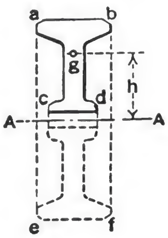
I. Base, abc, less than semicircle;
Convex Surface
$= h[2re - (d \times \text{length arc abc})] \div (r - d)$
Volume $= h\left[\frac{2}{3}e^3 - (d \times \text{area base abc})\right] \div (r - d)$

II. Base, abc = semicircle;
Convex Surface $= 2rh$ Volume $= \frac{2}{3}r^2h$

III. Base, abc, greater than semicircle (figure)
Convex Surface
$= h[2re + (d \times \text{length arc abc})] \div (r + d)$
Volume $= h\left[\frac{2}{3}e^3 + (d \times \text{area base abc})\right] \div (r + d)$

IV. Base, abc, = circle, oblique plane touching circumference.
Convex Surface $= \pi rh$ Volume $= \frac{1}{2}\pi r^2h$

V. Base, abc, = circle, oblique plane entirely above (figure)
Convex Surface $= 2\pi r$
$\times \frac{1}{2}(h, \text{minimum} + H, \text{maximum})$
Volume $= \pi r^2 \times \frac{1}{2}(h, \text{minimum} + H, \text{maximum})$



ANY SOLID OF REVOLUTION

Let abcd represent the generating section about axis A-A of solid abef.

Let g at distance h from A-A be the center of gravity of abcd.

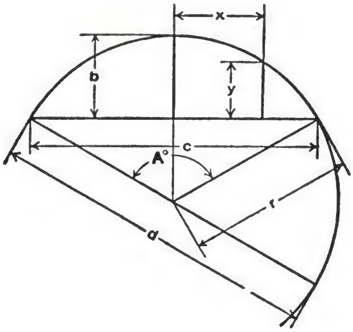
Let $\alpha°$ be the angular amount of generating revolution.

Then
Total Surface of solid abef
$= (2\pi h\alpha \div 360) \times$ perimeter abcd

Volume of solid abef $= (2\pi h\alpha \div 360) \times$ area abcd

For complete revolution $(2\pi h\alpha \div 360) = 2\pi h$

PROPERTIES OF THE CIRCLE



Circumference $= 6.28318\ r = 3.14159\ d$
Diameter $= 0.31831$ circumference
Area $= 3.14159\ r^2$

Arc $a = \dfrac{\pi r\ A^\circ}{180^\circ} = 0.017453\ r\ A^\circ$

Angle $A^\circ = \dfrac{180^\circ\ a}{\pi r} = 57.29578\ \dfrac{a}{r}$

Radius $r = \dfrac{4\ b^2 + c^2}{8\ b}$

Chord $c = 2\sqrt{2\ br - b^2} = 2\ r \sin \dfrac{A}{2}$

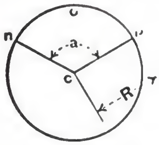
Rise $b = r - \frac{1}{2}\sqrt{4\ r^2 - c^2} = \dfrac{c}{2} \tan \dfrac{A}{4}$

$= 2\ r \sin^2 \dfrac{A}{4} = r + y - \sqrt{r^2 - x^2}$

$y = b - r + \sqrt{r^2 - x^2}$

$x = \sqrt{r^2 - (r + y - b)^2}$

Diameter of circle of equal periphery as square $= 1.27324$ side of square
Side of square of equal periphery as circle $= 0.78540$ diameter of circle
Diameter of circle circumscribed about square $= 1.41421$ side of square
Side of square inscribed in circle $= 0.70711$ diameter of circle

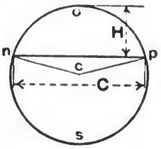


CIRCULAR SECTOR

R = radius of circle   a = angle ncp in degrees

Area of Sector ncpo $= \frac{1}{2}$ (length of arc nop $\times$ R) $=$ Area of Circle $\times \dfrac{a}{360}$

$= 0.0087266 \times R^2 \times a$



CIRCULAR SEGMENT

R = radius of circle   C = chord   H = rise

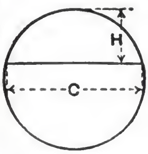
Area of Segment nop = Area of Sector ncpo—Area of triangle ncp

$= \dfrac{(\text{Length of arc nop} \times R) - C\,(R - H)}{2}$

Area of Segment nsp = Area of Circle − Area of Segment nop

CIRCULAR SEGMENT, From Table I,

Given: Rise, H, and Chord, C



Area = Coefficient $\times$ H $\times$ C

Coefficient found opposite $\dfrac{H}{C}$

Interpolate for intermediate values of $\dfrac{H}{C}$

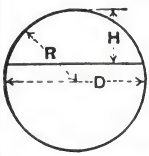
Example:
RISE = 1.49   CHORD = 3.52

$\dfrac{H}{C} = \dfrac{1.49}{3.52} = 0.4233$ Coeff. = 0.7542

Area = H $\times$ C $\times$ Coeff. = 1.49 $\times$ 3.52 $\times$ 0.7542 = 3.9556

CIRCULAR SEGMENT, From Table II,

Given: RISE, H, and DIAMETER, D = 2R



Area = Coefficient $\times$ D^2

Coefficient opposite $\dfrac{H}{D}$

Interpolate for intermediate values of $\dfrac{H}{D}$

Example:
RISE = $2\frac{7}{16}$ and DIAMETER = $5\frac{3}{32}$

$\dfrac{H}{D} = 2.4375 \div 5.09375 = 0.478528$

Coefficient = 0.371233

Area = Coef. $\times$ d^2 = 0.371233 $\times$ 25.94629 = 9.6321

See page D183 for Table I
See pages D184-5 for Table II

AREAS AND CIRCUMFERENCE OF CIRCLES

1/16 to 19 7/8

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
1/16	.0031	.1963	5	19.6350	15.7080	10	78.540	31.4160	15	176.715	47.1240
1/8	.0123	.3927	1/8	20.6290	16.1007	1/8	80.516	31.8087	1/8	179.673	47.5167
1/4	.0491	.7854	1/4	21.6476	16.4934	1/4	82.516	32.2014	1/4	182.655	47.9094
3/8	.1104	1.1781	3/8	22.6907	16.8861	3/8	84.541	32.5941	3/8	185.661	48.3021
1/2	.1963	1.5708	1/2	23.7583	17.2788	1/2	86.590	32.9868	1/2	188.692	48.6948
5/8	.3068	1.9635	5/8	24.8505	17.6715	5/8	88.664	33.3795	5/8	191.748	49.0875
3/4	.4418	2.3562	3/4	25.9673	18.0642	3/4	90.763	33.7722	3/4	194.828	49.4802
7/8	.6013	2.7489	7/8	27.1086	18.4569	7/8	92.886	34.1649	7/8	197.933	49.8729
1	.7854	3.1416	6	28.2744	18.8496	11	95.033	34.5576	16	201.062	50.2656
1/8	.9940	3.5343	1/8	29.4648	19.2423	1/8	97.205	34.9503	1/8	204.216	50.6583
1/4	1.2272	3.9270	1/4	30.6797	19.6350	1/4	99.402	35.3430	1/4	207.395	51.0510
3/8	1.4849	4.3197	3/8	31.9191	20.0277	3/8	101.623	35.7357	3/8	210.598	51.4437
1/2	1.7671	4.7124	1/2	33.1831	20.4204	1/2	103.869	36.1284	1/2	213.825	51.8364
5/8	2.0739	5.1051	5/8	34.4717	20.8131	5/8	106.139	36.5211	5/8	217.077	52.2291
3/4	2.4053	5.4978	3/4	35.7848	21.2058	3/4	108.434	36.9138	3/4	220.354	52.6218
7/8	2.7612	5.8905	7/8	37.1224	21.5985	7/8	110.754	37.3065	7/8	223.655	53.0145
2	3.1416	6.2832	7	38.4846	21.9912	12	113.098	37.6992	17	226.981	53.4072
1/8	3.5466	6.6759	1/8	39.8713	22.3839	1/8	115.466	38.0919	1/8	230.331	53.7999
1/4	3.9761	7.0686	1/4	41.2826	22.7766	1/4	117.859	38.4846	1/4	233.706	54.1926
3/8	4.4301	7.4613	3/8	42.7184	23.1693	3/8	120.277	38.8773	3/8	237.105	54.5853
1/2	4.9087	7.8540	1/2	44.1787	23.5620	1/2	122.719	39.2700	1/2	240.529	54.9780
5/8	5.4119	8.2467	5/8	45.6636	23.9547	5/8	125.185	39.6627	5/8	243.977	55.3707
3/4	5.9396	8.6394	3/4	47.1731	24.3474	3/4	127.677	40.0554	3/4	247.450	55.7634
7/8	6.4918	9.0321	7/8	48.7071	24.7401	7/8	130.192	40.4481	7/8	250.948	56.1561
3	7.0686	9.4248	8	50.2656	25.1328	13	132.733	40.8408	18	254.470	56.5488
1/8	7.6699	9.8175	1/8	51.8487	25.5255	1/8	135.297	41.2335	1/8	258.016	56.9415
1/4	8.2958	10.2102	1/4	53.4563	25.9182	1/4	137.887	41.6262	1/4	261.587	57.3342
3/8	8.9462	10.6029	3/8	55.0884	26.3109	3/8	140.501	42.0189	3/8	265.183	57.7269
1/2	9.6211	10.9956	1/2	56.7451	26.7036	1/2	143.139	42.4116	1/2	268.803	58.1196
5/8	10.3206	11.3883	5/8	58.4264	27.0963	5/8	145.802	42.8043	5/8	272.448	58.5123
3/4	11.0447	11.7810	3/4	60.1322	27.4890	3/4	148.490	43.1970	3/4	276.117	58.9050
7/8	11.7933	12.1737	7/8	61.8625	27.8817	7/8	151.202	43.5897	7/8	279.811	59.2977
4	12.5664	12.5664	9	63.6174	28.2744	14	153.938	43.9824	19	283.529	59.6904
1/8	13.3641	12.9591	1/8	65.3968	28.6671	1/8	156.700	44.3751	1/8	287.272	60.0831
1/4	14.1863	13.3518	1/4	67.2008	29.0598	1/4	159.485	44.7678	1/4	291.040	60.4758
3/8	15.0330	13.7445	3/8	69.0293	29.4525	3/8	162.296	45.1605	3/8	294.832	60.8685
1/2	15.9043	14.1372	1/2	70.8823	29.8452	1/2	165.130	45.5532	1/2	298.648	61.2612
5/8	16.8002	14.5299	5/8	72.7599	30.2379	5/8	167.990	45.9459	5/8	302.489	61.6539
3/4	17.7206	14.9226	3/4	74.6621	30.6306	3/4	170.874	46.3386	3/4	306.355	62.0466
7/8	18.6655	15.3153	7/8	76.5889	31.0233	7/8	173.782	46.7313	7/8	310.245	62.4393

AREAS AND CIRCUMFERENCE OF CIRCLES (Continued)

20 to 39⅞

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
20	314.160	62.8320	25	490.875	78.5400	30	706.860	94.248	35	962.115	109.956
⅛	318.099	63.2247	⅛	495.796	78.9327	⅛	712.763	94.641	⅛	969.000	110.349
¼	322.063	63.6174	¼	500.742	79.3254	¼	718.690	95.033	¼	975.909	110.741
⅜	326.051	64.0101	⅜	505.712	79.7181	⅜	724.642	95.426	⅜	982.842	111.134
½	330.064	64.4028	½	510.706	80.1108	½	730.618	95.819	½	989.800	111.527
⅝	334.102	64.7955	⅝	515.726	80.5035	⅝	736.619	96.212	⅝	996.783	111.919
¾	338.164	65.1828	¾	520.769	80.8962	¾	742.645	96.604	¾	1003.790	112.312
⅞	342.250	65.5809	⅞	525.838	81.2889	⅞	748.695	96.997	⅞	1010.822	112.705
21	346.361	65.9736	26	530.930	81.6816	31	754.769	97.390	36	1017.878	113.098
⅛	350.497	66.3663	⅛	536.048	82.0743	⅛	760.869	97.782	⅛	1024.960	113.490
¼	354.657	66.7590	¼	541.190	82.4670	¼	766.992	98.175	¼	1032.065	113.883
⅜	358.842	67.1517	⅜	546.356	82.8597	⅜	773.140	98.568	⅜	1039.195	114.276
½	363.051	67.5444	½	551.547	83.2524	½	779.313	98.960	½	1046.349	114.668
⅝	367.285	67.9371	⅝	556.763	83.6451	⅝	785.510	99.353	⅝	1053.528	115.061
¾	371.543	68.3298	¾	562.003	84.0378	¾	791.732	99.746	¾	1060.732	115.454
⅞	375.826	68.7225	⅞	567.267	84.4305	⅞	797.979	100.138	⅞	1067.960	115.846
22	380.134	69.1152	27	572.557	84.8232	32	804.250	100.531	37	1075.213	116.239
⅛	384.466	69.5079	⅛	577.870	85.2159	⅛	810.545	100.924	⅛	1082.490	116.632
¼	388.822	69.9006	¼	583.209	85.6086	¼	816.865	101.317	¼	1089.792	117.025
⅜	393.203	70.2933	⅜	588.571	86.0013	⅜	823.210	101.709	⅜	1097.118	117.417
½	397.609	70.6860	½	593.959	86.3940	½	829.579	102.102	½	1104.469	117.810
⅝	402.038	71.0787	⅝	599.371	86.7867	⅝	835.972	102.495	⅝	1111.844	118.203
¾	406.494	71.4714	¾	604.807	87.1794	¾	842.391	102.887	¾	1119.244	118.595
⅞	410.973	71.8641	⅞	610.268	87.5721	⅞	848.833	103.280	⅞	1126.669	118.988
23	415.477	72.2568	28	615.754	87.9648	33	855.301	103.673	38	1134.118	119.381
⅛	420.004	72.6495	⅛	621.264	88.3575	⅛	861.792	104.065	⅛	1141.591	119.773
¼	424 558	73.0422	¼	626.798	88.7502	¼	868.309	104.458	¼	1149.089	120.166
⅜	429.135	73.4349	⅜	632.357	89.1429	⅜	874.850	104.851	⅜	1156.612	120.559
½	433.737	73.8276	½	637.941	89.5356	½	881.415	105.244	½	1164.159	120.952
⅝	438.364	74.2203	⅝	643.549	89.9283	⅝	888.005	105.636	⅝	1171.731	121.344
¾	443.015	74.6130	¾	649.182	90.3210	¾	894.620	106.029	¾	1179.327	121.737
⅞	447.690	75.0057	⅞	654.840	90.7137	⅞	901.259	106.422	⅞	1186.948	122.130
24	452.390	75.3984	29	660.521	91.1064	34	907.922	106.814	39	1194.593	122.522
⅛	457.115	75.7911	⅛	666.228	91.4991	⅛	914.611	107.207	⅛	1202.263	122.915
¼	461.864	76.1838	¼	671.959	91.8918	¼	921.323	107.600	¼	1209.958	123.308
⅜	466.638	76.5765	⅜	677.714	92.2845	⅜	928.061	107.992	⅜	1217.677	123.700
½	471.436	76.9692	½	683.494	92.6772	½	934.822	108.385	½	1225.420	124.093
⅝	476.259	77.3619	⅝	689.299	93.0699	⅝	941.609	108.778	⅝	1233.188	124.486
¾	481.107	77.7546	¾	695.128	93.4626	¾	948.420	109.171	¾	1240.981	124.879
⅞	485.979	78.1473	⅞	700.982	93.8553	⅞	955.255	109.563	⅞	1248.798	125.271

AREAS AND CIRCUMFERENCE OF CIRCLES (Continued)

40 to 59 7/8

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
40	1256.64	125.664	45	1590.43	141.372	50	1963.50	157.080	55	2375.83	172.788
1/8	1264.51	126.057	1/8	1599.28	141.765	1/8	1973.33	157.473	1/8	2386.65	173.181
1/4	1272.40	126.449	1/4	1608.16	142.157	1/4	1983.18	157.865	1/4	2397.48	173.573
3/8	1280.31	126.842	3/8	1617.05	142.550	3/8	1993.06	158.258	3/8	2408.34	173.966
1/2	1288.25	127.235	1/2	1625.97	142.943	1/2	2002.97	158.651	1/2	2419.23	174.359
5/8	1296.22	127.627	5/8	1634.92	143.335	5/8	2012.89	159.043	5/8	2430.14	174.751
3/4	1304.21	128.020	3/4	1643.89	143.728	3/4	2022.85	159.436	3/4	2441.07	175.144
7/8	1312.22	128.413	7/8	1652.89	144.121	7/8	2032.82	159.829	7/8	2452.03	175.537
41	1320.26	128.806	46	1661.91	144.514	51	2042.83	160.222	56	2463.01	175.930
1/8	1328.32	129.198	1/8	1670.95	144.906	1/8	2052.85	160.614	1/8	2474.02	176.322
1/4	1336.41	129.591	1/4	1680.02	145.299	1/4	2062.90	161.007	1/4	2485.05	176.715
3/8	1344.52	129.984	3/8	1689.11	145.692	3/8	2072.98	161.400	3/8	2496.11	177.108
1/2	1352.66	130.376	1/2	1698.23	146.084	1/2	2083.08	161.792	1/2	2507.19	177.500
5/8	1360.82	130.769	5/8	1707.37	146.477	5/8	2093.20	162.185	5/8	2518.30	177.893
3/4	1369.00	131.162	3/4	1716.54	146.870	3/4	2103.35	162.578	3/4	2529.43	178.286
7/8	1377.21	131.554	7/8	1725.73	147.262	7/8	2113.52	162.970	7/8	2540.58	178.678
42	1385.45	131.947	47	1734.95	147.655	52	2123.72	163.363	57	2551.76	179.071
1/8	1393.70	132.340	1/8	1744.19	148.048	1/8	2133.94	163.756	1/8	2562.97	179.464
1/4	1401.99	132.733	1/4	1753.45	148.441	1/4	2144.19	164.149	1/4	2574.20	179.857
3/8	1410.30	133.125	3/8	1762.74	148.833	3/8	2154.46	164.541	3/8	2585.45	180.249
1/2	1418.63	133.518	1/2	1772.06	149.226	1/2	2164.76	164.934	1/2	2596.73	180.642
5/8	1426.99	133.911	5/8	1781.40	149.619	5/8	2175.08	165.327	5/8	2608.03	181.035
3/4	1435.37	134.303	3/4	1790.76	150.011	3/4	2185.42	165.719	3/4	2619.36	181.427
7/8	1443.77	134.696	7/8	1800.15	150.404	7/8	2195.79	166.112	7/8	2630.71	181.820
43	1452.20	135.089	48	1809.56	150.797	53	2206.19	166.505	58	2642.09	182.213
1/8	1460.66	135.481	1/8	1819.00	151.189	1/8	2216.61	166.897	1/8	2653.49	182.605
1/4	1469.14	135.874	1/4	1828.46	151.582	1/4	2227.05	167.290	1/4	2664.91	182.998
3/8	1477.64	136.267	3/8	1837.95	151.975	3/8	2237.52	167.683	3/8	2676.36	183.391
1/2	1486.17	136.660	1/2	1847.46	152.368	1/2	2248.01	168.076	1/2	2687.84	183.784
5/8	1494.73	137.052	5/8	1856.99	152.760	5/8	2258.53	168.468	5/8	2699.33	184.176
3/4	1503.30	137.445	3/4	1866.55	153.153	3/4	2269.07	168.861	3/4	2710.86	184.569
7/8	1511.91	137.838	7/8	1876.14	153.546	7/8	2279.64	169.254	7/8	2722.41	184.962
44	1520.53	138.230	49	1885.75	153.938	54	2290.23	169.646	59	2733.98	185.354
1/8	1529.19	138.623	1/8	1895.38	154.331	1/8	2300.84	170.039	1/8	2745.57	185.747
1/4	1537.86	139.016	1/4	1905.04	154.724	1/4	2311.48	170.432	1/4	2757.20	186.140
3/8	1546.56	139.408	3/8	1914.72	155.116	3/8	2322.15	170.824	3/8	2768.84	186.532
1/2	1555.29	139.801	1/2	1924.43	155.509	1/2	2332.83	171.217	1/2	2780.51	186.925
5/8	1564.04	140.194	5/8	1934.16	155.902	5/8	2343.55	171.610	5/8	2792.21	187.318
3/4	1572.81	140.587	3/4	1943.91	156.295	3/4	2354.29	172.003	3/4	2803.93	187.711
7/8	1581.61	140.979	7/8	1953.69	156.687	7/8	2365.05	172.395	7/8	2815.67	188.103

AREAS AND CIRCUMFERENCE OF CIRCLES (Continued)

60 to 79⅞

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
60	2827.44	188.496	65	3318.31	204.204	70	3848.46	219.912	75	4417.87	235.620
⅛	2839.23	188.889	⅛	3331.09	204.597	⅛	3862.22	220.305	⅛	4432.61	236.013
¼	2851.05	189.281	¼	3343.89	204.989	¼	3876.00	220.697	¼	4447.38	236.405
⅜	2862.89	189.674	⅜	3356.71	205.382	⅜	3889.80	221.090	⅜	4462.16	236.798
½	2874.76	190.067	½	3369.56	205.775	½	3903.63	221.483	½	4476.98	237.191
⅝	2886.65	190.459	⅝	3382.44	206.167	⅝	3917.49	221.875	⅝	4491.81	237.583
¾	2898.57	190.852	¾	3395.33	206.560	¾	3931.37	222.268	¾	4506.67	237.976
⅞	2910.51	191.245	⅞	3408.26	206.953	⅞	3945.27	222.661	⅞	4521.56	238.369
61	2922.47	191.638	66	3421.20	207.346	71	3959.20	223.054	76	4536.47	238.762
⅛	2934.46	192.030	⅛	3434.17	207.738	⅛	3973.15	223.446	⅛	4551.41	239.154
¼	2946.48	192.423	¼	3447.17	208.131	¼	3987.13	223.839	¼	4566.36	239.547
⅜	2958.52	192.816	⅜	3460.19	208.524	⅜	4001.13	224.232	⅜	4581.35	239.940
½	2970.58	193.208	½	3473.24	208.916	½	4015.16	224.624	½	4596.36	240.332
⅝	2982.67	193.601	⅝	3486.30	209.309	⅝	4029.21	225.017	⅝	4611.39	240.725
¾	2994.78	193.994	¾	3499.40	209.702	¾	4043.29	225.410	¾	4626.45	241.118
⅞	3006.92	194.386	⅞	3512.52	210.094	⅞	4057.39	225.802	⅞	4641.53	241.510
62	3019.08	194.779	67	3525.66	210.487	72	4071.51	226.195	77	4656.64	241.903
⅛	3031.26	195.172	⅛	3538.83	210.880	⅛	4085.66	226.588	⅛	4671.77	242.296
¼	3043.47	195.565	¼	3552.02	211.273	¼	4099.84	226.981	¼	4686.92	242.689
⅜	3055.71	195.957	⅜	3565.24	211.665	⅜	4114.04	227.373	⅜	4702.10	243.081
½	3067.97	196.350	½	3578.48	212.058	½	4128.26	227.766	½	4717.31	243.474
⅝	3080.25	196.743	⅝	3591.74	212.451	⅝	4142.51	228.159	⅝	4732.54	243.867
¾	3092.56	197.135	¾	3605.04	212.843	¾	4156.78	228.551	¾	4747.79	244.259
⅞	3104.89	197.528	⅞	3618.35	213.236	⅞	4171.08	228.944	⅞	4763.07	244.652
63	3117.25	197.921	68	3631.69	213.629	73	4185.40	229.337	78	4778.37	245.045
⅛	3129.64	198.313	⅛	3645.05	214.021	⅛	4199.74	229.729	⅛	4793.70	245.437
¼	3142.04	198.706	¼	3658.44	214.414	¼	4214.11	230.122	¼	4809.05	245.830
⅜	3154.47	199.099	⅜	3671.86	214.807	⅜	4228.51	230.515	⅜	4824.43	246.223
½	3166.93	199.492	½	3685.29	215.200	½	4242.93	230.908	½	4839.83	246.616
⅝	3179.41	199.884	⅝	3698.76	215.592	⅝	4257.37	231.300	⅝	4855.26	247.008
¾	3191.91	200.277	¾	3712.24	215.985	¾	4271.84	231.693	¾	4870.71	247.401
⅞	3204.44	200.670	⅞	3725.75	216.378	⅞	4286.33	232.086	⅞	4886.18	247.794
64	3217.00	201.062	69	3739.29	216.770	74	4300.85	232.478	79	4901.68	248.186
⅛	3229.58	201.455	⅛	3752.85	217.163	⅛	4315.39	232.871	⅛	4917.21	248.579
¼	3242.18	201.848	¼	3766.43	217.556	¼	4329.96	233.264	¼	4932.75	248.972
⅜	3254.81	202.240	⅜	3780.04	217.948	⅜	4344.55	233.656	⅜	4948.33	249.364
½	3267.46	202.633	½	3793.68	218.341	½	4359.17	234.049	½	4963.92	249.757
⅝	3280.14	203.026	⅝	3807.34	218.734	⅝	4373.81	234.442	⅝	4979.55	250.150
¾	3292.84	203.419	¾	3821.02	219.127	¾	4388.47	234.835	¾	4995.19	250.543
⅞	3305.56	203.811	⅞	3834.73	219.519	⅞	4403.16	235.227	⅞	5010.86	250.935

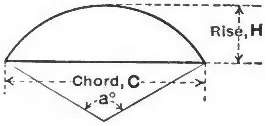
AREAS AND CIRCUMFERENCE OF CIRCLES (Continued)

80 to 100

Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference	Diameter	Area	Circumference
80	5026.56	251.328	85	5674.51	267.036	90	6361.74	282.744	95	7088.24	298.452
⅛	5042.28	251.721	⅛	5691.22	267.429	⅛	6379.42	283.137	⅛	7106.90	298.845
¼	5058.03	252.113	¼	5707.94	267.821	¼	6397.13	283.529	¼	7125.59	299.237
⅜	5073.79	252.506	⅜	5724.69	268.214	⅜	6414.86	283.922	⅜	7144.31	299.630
½	5089.59	252.899	½	5741.47	268.607	½	6432.62	284.315	½	7163.04	300.023
⅝	5105.41	253.291	⅝	5758.27	268.999	⅝	6450.40	284.707	⅝	7181.81	300.415
¾	5121.25	253.684	¾	5775.10	269.392	¾	6468.21	285.100	¾	7200.60	300.808
⅞	5137.12	254.077	⅞	5791.94	269.785	⅞	6486.04	285.493	⅞	7219.41	301.201
81	5153.01	254.470	86	5808.82	270.178	91	6503.90	285.886	96	7238.25	301.594
⅛	5168.93	254.862	⅛	5825.72	270.570	⅛	6521.78	286.278	⅛	7257.11	301.986
¼	5184.87	255.255	¼	5842.64	270.963	¼	6539.68	286.671	¼	7275.99	302.379
⅜	5200.83	255.648	⅜	5859.59	271.356	⅜	6557.61	287.064	⅜	7294.91	302.772
½	5216.82	256.040	½	5876.56	271.748	½	6575.56	287.456	½	7313.84	303.164
⅝	5232.84	256.433	⅝	5893.55	272.141	⅝	6593.54	287.849	⅝	7332.80	303.557
¾	5248.88	256.826	¾	5910.58	272.534	¾	6611.55	288.242	¾	7351.79	303.950
⅞	5264.94	257.218	⅞	5927.62	272.926	⅞	6629.57	288.634	⅞	7370.79	304.342
82	5281.03	257.611	87	5944.69	273.319	92	6647.63	289.027	97	7389.83	304.735
⅛	5297.14	258.004	⅛	5961.79	273.712	⅛	6665.70	289.420	⅛	7408.89	305.128
¼	5313.28	258.397	¼	5978.91	274.105	¼	6683.80	289.813	¼	7427.97	305.521
⅜	5329.44	258.789	⅜	5996.05	274.497	⅜	6701.93	290.205	⅜	7447.08	305.913
½	5345.63	259.182	½	6013.22	274.890	½	6720.08	290.598	½	7466.21	306.306
⅝	5361.84	259.575	⅝	6030.41	275.283	⅝	6738.25	290.991	⅝	7485.37	306.699
¾	5378.08	259.967	¾	6047.63	275.675	¾	6756.45	291.383	¾	7504.55	307.091
⅞	5394.34	260.360	⅞	6064.87	276.068	⅞	6774.68	291.776	⅞	7523.75	307.484
83	5410.62	260.753	88	6082.14	276.461	93	6792.92	292.169	98	7542.98	307.877
⅛	5426.93	261.145	⅛	6099.43	276.853	⅛	6811.20	292.562	⅛	7562.24	308.270
¼	5443.26	261.538	¼	6116.74	277.246	¼	6829.49	292.954	¼	7581.52	308.662
⅜	5459.62	261.931	⅜	6134.08	277.638	⅜	6847.82	293.347	⅜	7600.82	309.055
½	5476.01	262.324	½	6151.45	278.032	½	6866.16	293.740	½	7620.15	309.448
⅝	5492.41	262.716	⅝	6168.84	278.424	⅝	6884.53	294.132	⅝	7639.50	309.840
¾	5508.84	263.109	¾	6186.25	278.817	¾	6902.93	294.525	¾	7658.88	310.233
⅞	5525.30	263.502	⅞	6203.69	279.210	⅞	6921.35	294.918	⅞	7678.28	310.626
84	5541.78	263.894	89	6221.15	279.602	94	6939.79	295.310	99	7697.71	311.018
⅛	5558.29	264.287	⅛	6238.64	279.995	⅛	6958.26	295.703	⅛	7717.16	311.411
¼	5574.82	264.680	¼	6256.15	280.388	¼	6976.76	296.096	¼	7736.63	311.804
⅜	5591.37	265.072	⅜	6273.69	280.780	⅜	6995.28	296.488	⅜	7756.13	312.196
½	5607.95	265.465	½	6291.25	281.173	½	7013.82	296.881	½	7775.66	312.589
⅝	5624.56	265.858	⅝	6308.84	281.566	⅝	7032.39	297.274	⅝	7795.21	312.982
¾	5641.18	266.251	¾	6326.45	281.959	¾	7050.98	297.667	¾	7814.78	313.375
⅞	5657.84	266.643	⅞	6344.08	282.351	⅞	7069.59	298.059	⅞	7834.38	313.767
									100	7854.00	314.160

AREAS OF CIRCULAR SEGMENTS

Table I – For Ratios of Rise and Chord

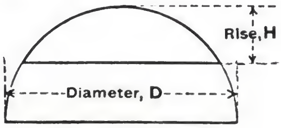


Area = C x H x coefficient

a	Coeffi-cient	H/C	a	Coeffi-cient	H/C	a	Coeffi-cient	H/C	a	Coeffi-cient	H/C
1	.6667	.0022	46	.6722	.1017	91	.6895	.2097	136	.7239	.3373
2	.6667	.0044	47	.6724	.1040	92	.6901	.2122	137	.7249	.3404
3	.6667	.0066	48	.6727	.1063	93	.6906	.2148	138	.7260	.3436
4	.6667	.0087	49	.6729	.1086	94	.6912	.2174	139	.7270	.3469
5	.6667	.0109	50	.6732	.1109	95	.6918	.2200	140	.7281	.3501
6	.6667	.0131	51	.6734	.1131	96	.6924	.2226	141	.7292	.3534
7	.6668	.0153	52	.6737	.1154	97	.6930	.2252	142	.7303	.3567
8	.6668	.0175	53	.6740	.1177	98	.6936	.2279	143	.7314	.3600
9	.6669	.0197	54	.6743	.1200	99	.6942	.2305	144	.7325	.3633
10	.6670	.0218	55	.6746	.1224	100	.6948	.2332	145	.7336	.3666
11	.6670	.0240	56	.6749	.1247	101	.6954	.2358	146	.7348	.3700
12	.6671	.0262	57	.6752	.1270	102	.6961	.2385	147	.7360	.3734
13	.6672	.0284	58	.6755	.1293	103	.6967	.2412	148	.7372	.3768
14	.6672	.0306	59	.6758	.1316	104	.6974	.2439	149	.7384	.3802
15	.6673	.0328	60	.6761	.1340	105	.6980	.2466	150	.7396	.3837
16	.6674	.0350	61	.6764	.1363	106	.6987	.2493	151	.7408	.3871
17	.6674	.0372	62	.6768	.1387	107	.6994	.2520	152	.7421	.3906
18	.6675	.0394	63	.6771	.1410	108	.7001	.2548	153	.7434	.3942
19	.6676	.0416	64	.6775	.1434	109	.7008	.2575	154	.7447	.3977
20	.6677	.0437	65	.6779	.1457	110	.7015	.2603	155	.7460	.4013
21	.6678	.0459	66	.6782	.1481	111	.7022	.2631	156	.7473	.4049
22	.6679	.0481	67	.6786	.1505	112	.7030	.2659	157	.7486	.4085
23	.6680	.0504	68	.6790	.1529	113	.7037	.2687	158	.7500	.4122
24	.6681	.0526	69	.6794	.1553	114	.7045	.2715	159	.7514	.4159
25	.6682	.0548	70	.6797	.1577	115	.7052	.2743	160	.7528	.4196
26	.6684	.0570	71	.6801	.1601	116	.7060	.2772	161	.7542	.4233
27	.6685	.0592	72	.6805	.1625	117	.7068	.2800	162	.7557	.4270
28	.6687	.0614	73	.6809	.1649	118	.7076	.2829	163	.7571	.4308
29	.6688	.0636	74	.6814	.1673	119	.7084	.2858	164	.7586	.4346
30	.6690	.0658	75	.6818	.1697	120	.7092	.2887	165	.7601	.4385
31	.6691	.0681	76	.6822	.1722	121	.7100	.2916	166	.7616	.4424
32	.6693	.0703	77	.6826	.1746	122	.7109	.2945	167	.7632	.4463
33	.6694	.0725	78	.6831	.1771	123	.7117	.2975	168	.7648	.4502
34	.6696	.0747	79	.6835	.1795	124	.7126	.3004	169	.7664	.4542
35	.6698	.0770	80	.6840	.1820	125	.7134	.3034	170	.7680	.4582
36	.6700	.0792	81	.6844	.1845	126	.7143	.3064	171	.7696	.4622
37	.6702	.0814	82	.6849	.1869	127	.7152	.3094	172	.7712	.4663
38	.6704	.0837	83	.6854	.1894	128	.7161	.3124	173	.7729	.4704
39	.6706	.0859	84	.6859	.1919	129	.7170	.3155	174	.7746	.4745
40	.6708	.0882	85	.6864	.1944	130	.7180	.3185	175	.7763	.4787
41	.6710	.0904	86	.6869	.1970	131	.7189	.3216	176	.7781	.4828
42	.6712	.0927	87	.6874	.1995	132	.7199	.3247	177	.7799	.4871
43	.6714	.0949	88	.6879	.2020	133	.7209	.3278	178	.7817	.4914
44	.6717	.0972	89	.6884	.2046	134	.7219	.3309	179	.7835	.4957
45	.6719	.0995	90	.6890	.2071	135	.7229	.3341	180	.7854	.5000

AREAS OF CIRCULAR SEGMENTS (Continued)

Table II – For Ratios of Rise and Diameter

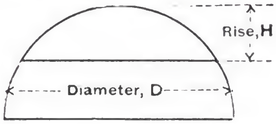


Area = D^2 x Coefficient

H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient
.001	.000042	.051	.015119	.101	.041477	.151	.074590	.201	.112625
.002	.000119	.052	.015561	.102	.042081	.152	.075307	.202	.113427
.003	.000219	.053	.016008	.103	.042687	.153	.076026	.203	.114231
.004	.000337	.054	.016458	.104	.043296	.154	.076747	.204	.115036
.005	.000471	.055	.016912	.105	.043908	.155	.077470	.205	.115842
.006	.000619	.056	.017369	.106	.044523	.156	.078194	.206	.116651
.007	.000779	.057	.017831	.107	.045140	.157	.078921	.207	.117460
.008	.000952	.058	.018297	.108	.045759	.158	.079650	.208	.118271
.009	.001135	.059	.018766	.109	.046381	.159	.080380	.209	.119084
.010	.001329	.060	.019239	.110	.047006	.160	.081112	.210	.119898
.011	.001533	.061	.019716	.111	.047633	.161	.081847	.211	.120713
.012	.001746	.062	.020197	.112	.048262	.162	.082582	.212	.121530
.013	.001969	.063	.020681	.113	.048894	.163	.083320	.213	.122348
.014	.002199	.064	.021168	.114	.049529	.164	.084060	.214	.123167
.015	.002438	.065	.021660	.115	.050165	.165	.084801	.215	.123988
.016	.002685	.066	.022155	.116	.050805	.166	.085545	.216	.124811
.017	.002940	.067	.022653	.117	.051446	.167	.086290	.217	.125634
.018	.003202	.068	.023155	.118	.052090	.168	.087037	.218	.126459
.019	.003472	.069	.023660	.119	.052737	.169	.087785	.219	.127286
.020	.003749	.070	.024168	.120	.053385	.170	.088536	.220	.128114
.021	.004032	.071	.024680	.121	.054037	.171	.089288	.221	.128943
.022	.004322	.072	.025196	.122	.054690	.172	.090042	.222	.129773
.023	.004619	.073	.025714	.123	.055346	.173	.090797	.223	.130605
.024	.004922	.074	.026236	.124	.056004	.174	.091555	.224	.131438
.025	.005231	.075	.026761	.125	.056664	.175	.092314	.225	.132273
.026	.005546	.076	.027290	.126	.057327	.176	.093074	.226	.133109
.027	.005867	.077	.027821	.127	.057991	.177	.093837	.227	.133946
.028	.006194	.078	.028356	.128	.058658	.178	.094601	.228	.134784
.029	.006527	.079	.028894	.129	.059328	.179	.095367	.229	.135624
.030	.006866	.080	.029435	.130	.059999	.180	.096135	.230	.136465
.031	.007209	.081	.029979	.131	.060673	.181	.096904	.231	.137307
.032	.007559	.082	.030526	.132	.061349	.182	.097675	.232	.138151
.033	.007913	.083	.031077	.133	.062027	.183	.098447	.233	.138996
.034	.008273	.084	.031630	.134	.062707	.184	.099221	.234	.139842
.035	.008638	.085	.032186	.135	.063389	.185	.099997	.235	.140689
.036	.009008	.086	.032746	.136	.064074	.186	.100774	.236	.141538
.037	.009383	.087	.033308	.137	.064761	.187	.101553	.237	.142388
.038	.009764	.088	.033873	.138	.065449	.188	.102334	.238	.143239
.039	.010148	.089	.034441	.139	.066140	.189	.103116	.239	.144091
.040	.010538	.090	.035012	.140	.066833	.190	.103900	.240	.144945
.041	.010932	.091	.035586	.141	.067528	.191	.104686	.241	.145800
.042	.011331	.092	.036162	.142	.068225	.192	.105472	.242	.146656
.043	.011734	.093	.036742	.143	.068924	.193	.106261	.243	.147513
.044	.012142	.094	.037324	.144	.069626	.194	.107051	.244	.148371
.045	.012555	.095	.037909	.145	.070329	.195	.107843	.245	.149231
.046	.012971	.096	.038497	.146	.071034	.196	.108636	.246	.150091
.047	.013393	.097	.039087	.147	.071741	.197	.109431	.247	.150953
.048	.013818	.098	.039681	.148	.072450	.198	.110227	.248	.151816
.049	.014248	.099	.040277	.149	.073162	.199	.111025	.249	.152681
.050	.014681	.100	.040875	.150	.073875	.200	.111824	.250	.153546

AREAS OF CIRCULAR SEGMENTS (Continued)

Table II – For Ratios of Rise and Diameter



Area = D^2 x Coefficient

H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient	H/D	Coefficient
.251	.154413	.301	.199085	.351	.245935	.401	.294350	.451	.343778
.252	.155281	.302	.200003	.352	.246890	.402	.295330	.452	.344773
.253	.156149	.303	.200922	.353	.247845	.403	.296311	.453	.345768
.254	.157019	.304	.201841	.354	.248801	.404	.297292	.454	.346764
.255	.157891	.305	.202762	.355	.249758	.405	.298274	.455	.347760
.256	.158763	.306	.203683	.356	.250715	.406	.299256	.456	.348756
.257	.159636	.307	.204605	.357	.251673	.407	.300238	.457	.349752
.258	.160511	.308	.205528	.358	.252632	.408	.301221	.458	.350749
.259	.161386	.309	.206452	.359	.253591	.409	.302204	.459	.351745
.260	.162263	.310	.207376	.360	.254551	.410	.303187	.460	.352742
.261	.163141	.311	.208302	.361	.255511	.411	.304171	.461	.353739
.262	.164020	.312	.209228	.362	.256472	.412	.305156	.462	.354736
.263	.164900	.313	.210155	.363	.257433	.413	.306140	.463	.355733
.264	.165781	.314	.211083	.364	.258395	.414	.307125	.464	.356730
.265	.166663	.315	.212011	.365	.259358	.415	.308110	.465	.357728
.266	.167546	.316	.212941	.366	.260321	.416	.309096	.466	.358725
.267	.168431	.317	.213871	.367	.261285	.417	.310082	.467	.359723
.268	.169316	.318	.214802	.368	.262249	.418	.311068	.468	.360721
.269	.170202	.319	.215734	.369	.263214	.419	.312055	.469	.361719
.270	.171090	.320	.216666	.370	.264179	.420	.313042	.470	.362717
.271	.171978	.321	.217600	.371	.265145	.421	.314029	.471	.363715
.272	.172868	.322	.218534	.372	.266111	.422	.315017	.472	.364714
.273	.173758	.323	.219469	.373	.267078	.423	.316005	.473	.365712
.274	.174650	.324	.220404	.374	.268046	.424	.316993	.474	.366711
.275	.175542	.325	.221341	.375	.269014	.425	.317981	.475	.367710
.276	.176436	.326	.222278	.376	.269982	.426	.318970	.476	.368708
.277	.177330	.327	.223216	.377	.270951	.427	.319959	.477	.369707
.278	.178226	.328	.224154	.378	.271921	.428	.320949	.478	.370706
.279	.179122	.329	.225094	.379	.272891	.429	.321938	.479	.371705
.280	.180020	.330	.226034	.380	.273861	.430	.322928	.480	.372704
.281	.180918	.331	.226974	.381	.274832	.431	.323919	.481	.373704
.282	.181818	.332	.227916	.382	.275804	.432	.324909	.482	.374703
.283	.182718	.333	.228858	.383	.276776	.433	.325900	.483	.375702
.284	.183619	.334	.229801	.384	.277748	.434	.326891	.484	.376702
.285	.184522	.335	.230745	.385	.278721	.435	.327883	.485	.377701
.286	.185425	.336	.231689	.386	.279695	.436	.328874	.486	.378701
.287	.186329	.337	.232634	.387	.280669	.437	.329866	.487	.379701
.288	.187235	.338	.233580	.388	.281643	.438	.330858	.488	.380700
.289	.188141	.339	.234526	.389	.282618	.439	.331851	.489	.381700
.290	.189048	.340	.235473	.390	.283593	.440	.332843	.490	.382700
.291	.189956	.341	.236421	.391	.284569	.441	.333836	.491	.383700
.292	.190865	.342	.237369	.392	.285545	.442	.334829	.492	.384699
.293	.191774	.343	.238319	.393	.286521	.443	.335823	.493	.385699
.294	.192685	.344	.239268	.394	.287499	.444	.336816	.494	.386699
.295	.193597	.345	.240219	.395	.288476	.445	.337810	.495	.387699
.296	.194509	.346	.241170	.396	.289454	.446	.338804	.496	.388699
.297	.195423	.347	.242122	.397	.290432	.447	.339799	.497	.389699
.298	.196337	.348	.243074	.398	.291411	.448	.340793	.498	.390699
.299	.197252	.349	.244027	.399	.292390	.449	.341788	.499	.391699
.300	.198168	.350	.244980	.400	.293370	.450	.342783	.500	.392699

SEGMENTS OF THE CIRCLE

1 to 90 Degrees

Central Angle		A/R²	C/R	H/R	H/C	Central Angle		A/R²	C/R	H/R	H/C
a° Degree	a_r Radians	Area / Radius²	Chord / Radius	Height / Radius	Height / Chord	a° Degree	a_r Radians	Area / Radius²	Chord / Radius	Height / Radius	Height / Chord
1	.017453	.(6)44304	.017453	.(4)38077	.0021817	46	.802851	.0417559	.781462	.0794951	.101726
2	.034907	.(5)35442	.034905	.(3)15230	.0043634	47	.820305	.0444755	.797498	.0829399	.104000
3	.052360	.(4)11961	.052354	.(3)34268	.0065454	48	.837758	.0473066	.813473	.0864545	.106278
4	.069813	.(4)28348	.069799	.(3)60917	.0087275	49	.855211	.0502509	.829386	.0900387	.108561
5	.087266	.(4)55360	.087239	.(3)95178	.0109100	50	.872665	.0533101	.845237	.0936922	.110847
6	.104720	.(4)95646	.104672	.(2)13705	.0130929	51	.890118	.0564860	.861022	.0974147	.113138
7	.122173	.(3)15185	.122097	.(2)18652	.0152764	52	.907571	.0597802	.876742	.101206	.115434
8	.139626	.(3)22662	.139513	.(2)24359	.0174604	53	.925025	.0631945	.892396	.105066	.117734
9	.157080	.(3)32258	.156918	.(2)30827	.0196451	54	.942478	.0667304	.907981	.108994	.120039
10	.174533	.(3)44237	.174311	.(2)38053	.0218305	55	.959931	.0703896	.923497	.112989	.122349
11	.191986	.(3)58861	.191692	.(2)46038	.0240167	56	.977384	.0741734	.938943	.117052	.124664
12	.209440	.(3)76391	.209057	.(2)54781	.0262039	57	.994838	.0780836	.954318	.121183	.126984
13	.226893	.(3)97087	.226406	.(2)64281	.0283921	58	1.012291	.0821215	.969619	.125380	.129309
14	.244346	.(2)12121	.243739	.(2)74538	.0305813	59	1.029744	.0862885	.984847	.129644	.131639
15	.261799	.(2)14902	.261052	.(2)85551	.0327717	60	1.047198	.0905861	1.000000	.133975	.133975
16	.279253	.(2)18077	.278346	(2)97319	.0349634	61	1.064651	.0950156	1.015077	.138371	.136316
17	.296706	.(2)21671	.295619	.0109841	.0371564	62	1.082104	.0995783	1.030076	.142833	.138662
18	.314159	.(2)25711	.312869	.0123117	.0393509	63	1.099557	.1042754	1.044997	.147360	.141015
19	.331613	.(2)30222	.330095	.0137144	.0415468	64	1.117011	.109108	1.059839	.151952	.143373
20	.349066	.(2)35229	.347296	.0151922	.0437443	65	1.134464	.114078	1.074599	.156609	.145737
21	.366519	.(2)40756	.364471	.0167451	.0459436	66	1.151917	.119186	1.089278	.161329	.148107
22	.383972	.(2)46829	.381618	.0183728	.0481445	67	1.169371	.124433	1.103874	.166114	.150483
23	.401426	.(2)53473	.398736	.0200753	.0503474	68	1.186824	.129820	1.118386	.170962	.152865
24	.418879	.(2)60712	.415823	.0218524	.0525521	69	1.204277	.135348	1.132812	.175874	.155254
25	.436332	.(2)68570	.432879	.0237040	.0547589	70	1.221730	.141019	1.147153	.180848	.157649
26	.453786	.(2)77072	.449902	.0256299	.0569678	71	1.239184	.146833	1.161406	.185885	.160051
27	.471239	.(2)86242	.466891	.0276301	.0591789	72	1.256637	.152790	1.175571	.190983	.162460
28	.488692	.(2)96103	.483844	.0297043	.0613923	73	1.274090	.158893	1.189646	.196143	.164875
29	.506145	.0106680	.500760	.0318524	.0636081	74	1.291544	.165141	1.203630	.201365	.167298
30	.523599	.0117994	.517638	.0340742	.0658263	75	1.308997	.171536	1.217523	.206647	.169727
31	.541052	.0130070	.534477	.0363695	.0680469	76	1.326450	.178077	1.231323	.211989	.172164
32	.558505	.0142931	.551275	.0387383	.0702704	77	1.343904	.184767	1.245029	.217392	.174608
33	.575959	.0156599	.568031	.0411803	.0724966	78	1.361357	.191605	1.258641	.222854	.177059
34	.593412	.0171095	.584743	.0436952	.0747254	79	1.378810	.198591	1.272156	.228375	.179518
35	.610865	.0186444	.601412	.0462830	.0769573	80	1.396263	.205728	1.285575	.233956	.181985
36	.628319	.0202666	.618034	.0489435	.0791922	81	1.413717	.213014	1.298896	.239594	.184460
37	.645772	.0219784	.634609	.0516763	.0814301	82	1.431170	.220451	1.312118	.245290	.186942
38	.663225	.0237818	.651136	.0544814	.0836713	83	1.448623	.228039	1.325240	.251044	.189433
39	.680678	.0256790	.667614	.0573585	.0859157	84	1.466077	.235777	1.338261	.256855	.191932
40	.698132	.0276721	.684040	.0603074	.0881635	85	1.483530	.243668	1.351180	.262723	.194439
41	.715585	.0297630	.700415	.0633278	.0904147	86	1.500983	.251710	1.363997	.268646	.196955
42	.733038	.0319539	.716736	.0664196	.0926696	87	1.518436	.259903	1.376709	.274626	.199480
43	.750492	.0342466	.733002	.0695824	.0949279	88	1.535890	.268249	1.389317	.280660	.202013
44	.767945	.0366433	.749213	.0728161	.0971901	89	1.553343	.276748	1.401819	.286750	.204555
45	.785398	.0391457	.765367	.0761205	.0994562	90	1.570796	.285398	1.414214	.292893	.207107

For angles a° less than 1°: Radians, a_r = .01745329 a°: A/R² = .(6)44304 $a^{\circ 3}$
C/R = .0174531 a°: H/R = .000038077 $a^{\circ 2}$
H/C = .00218167 a°.

SEGMENTS OF THE CIRCLE (Continued)

91 to 180 Degrees

Central Angle		A/R²	C/R	H/R	H/C	Central Angle		A/R²	C/R	H/R	H/C
$a°$ Degree	a_r Radians	Area / Radius²	Chord / Radius	Height / Radius	Height / Chord	$a°$ Degree	a_r Radians	Area / Radius²	Chord / Radius	Height / Radius	Height / Chord
91	1.588250	.294201	1.426501	.299091	.209667	136	2.373648	.839495	1.854368	.625393	.337254
92	1.605703	.303156	1.438680	.305342	.212237	137	2.391101	.854551	1.860835	.633499	.340438
93	1.623156	.312263	1.450749	.311645	.214817	138	2.408554	.869712	1.867161	.641632	.343641
94	1.640609	.321523	1.462707	.318002	.217406	139	2.426008	.884974	1.873344	.649793	.346862
95	1.658063	.330934	1.474555	.324410	.220005	140	2.443461	.900337	1.879385	.657980	.350104
96	1.675516	.340497	1.486290	.330869	.222614	141	2.460914	.915797	1.885283	.666193	.353365
97	1.692969	.350212	1.497911	.337380	.225234	142	2.478368	.931353	1.891037	.674432	.356647
98	1.710423	.360077	1.509419	.343941	.227863	143	2.495821	.947003	1.896647	.682695	.359948
99	1.727876	.370094	1.520812	.350552	.230503	144	2.513274	.962744	1.902113	.690983	.363271
100	1.745329	.380261	1.532089	.357212	.233154	145	2.530727	.978576	1.907434	.699294	.366615
101	1.762783	.390578	1.543249	.363922	.235815	146	2.548181	.994494	1.912610	.707628	.369981
102	1.780236	.401044	1.554292	.370680	.238488	147	2.565634	1.010498	1.917639	.715985	.373368
103	1.797689	.411660	1.565216	.377485	.241171	148	2.583087	1.026584	1.922523	.724363	.376777
104	1.815142	.422423	1.576022	.384339	.243866	149	2.600541	1.042751	1.927261	.732762	.380209
105	1.832596	.433335	1.586707	.391239	.246573	150	2.617994	1.058997	1.931852	.741181	.383664
106	1.850049	.444394	1.597271	.398185	.249291	151	2.635447	1.075319	1.936295	.749620	.387141
107	1.867502	.455599	1.607714	.405177	.252021	152	2.652900	1.091714	1.940591	.758078	.390643
108	1.884955	.466950	1.618034	.412215	.254763	153	2.670354	1.108182	1.944740	.766555	.394168
109	1.902409	.478445	1.628231	.419297	.257517	154	2.687807	1.124718	1.948740	.775049	.397718
110	1.919862	.490085	1.638304	.426424	.260284	155	2.705260	1.141321	1.952592	.783560	.401292
111	1.937315	.501868	1.648252	.433594	.263063	156	2.722714	1.157989	1.956295	.792088	.404892
112	1.954769	.513792	1.658075	.440807	.265855	157	2.740167	1.174718	1.959849	.800632	.408517
113	1.972222	.525859	1.667772	.448063	.268660	158	2.757620	1.191507	1.963254	.809191	.412168
114	1.989675	.538065	1.677341	.455361	.271478	159	2.775074	1.208353	1.966510	.817765	.415846
115	2.007129	.550410	1.686783	.462700	.274309	160	2.792527	1.225253	1.969616	.826352	.419550
116	2.024582	.562894	1.696096	.470081	.277155	161	2.809980	1.242206	1.972571	.834952	.423281
117	2.042035	.575514	1.705280	.477501	.280013	162	2.827433	1.259208	1.975377	.843566	.427040
118	2.059489	.588270	1.714335	.484962	.282886	163	2.844887	1.276258	1.978032	.852191	.430828
119	2.076942	.601161	1.723258	.492462	.285774	164	2.862340	1.293351	1.980536	.860827	.434643
120	2.094395	.614185	1.732051	.500000	.288675	165	2.879793	1.310487	1.982890	.869474	.438488
121	2.111848	.627341	1.740711	.507576	.291591	166	2.897247	1.327662	1.985092	.878131	.442363
122	2.129302	.640627	1.749239	.515190	.294523	167	2.914700	1.344874	1.987144	.886797	.446267
123	2.146755	.654042	1.757634	.522841	.297469	168	2.932153	1.362121	1.989044	.895472	.450202
124	2.164208	.667585	1.765895	.530528	.300430	169	2.949606	1.379399	1.990792	.904154	.454168
125	2.181662	.681255	1.774022	.538251	.303407	170	2.967060	1.396706	1.992389	.912844	.453166
126	2.199115	.695049	1.782013	.546010	.306400	171	2.984513	1.414039	1.993835	.921541	.462195
127	2.216568	.708966	1.789869	.553802	.309409	172	3.001966	1.431397	1.995128	.930244	.466258
128	2.234021	.723005	1.797588	.561629	.312435	173	3.019420	1.448775	1.996270	.938952	.470353
129	2.251475	.737164	1.805171	.569489	.315476	174	3.036873	1.466172	1.997259	.947664	.474482
130	2.268928	.751442	1.812616	.577382	.318535	175	3.054326	1.483585	1.998096	.956381	.478646
131	2.286381	.765836	1.819923	.585307	.321611	176	3.071779	1.501012	1.998782	.965101	.482844
132	2.303835	.780345	1.827091	.593263	.324704	177	3.089233	1.518448	1.999315	.973823	.487078
133	2.321288	.794967	1.834120	.601251	.327814	178	3.106686	1.535893	1.999695	.982548	.491349
134	2.338741	.809701	1.841010	.609269	.330943	179	3.124139	1.553343	1.999924	.991274	.495656
135	2.356194	.824544	1.847759	.617317	.334089	180	3.141593	1.570796	2.000000	1.000000	.500000

LENGTH OF CIRCULAR ARCS FOR UNIT RADIUS

By the use of this table, the length of any arc may be found if the length of the radius and the angle of the segment are known.

Example:—Required the length of arc of segment of 32° 15′ 27″ with radius of 24 feet 3 inches.

From table: Length of arc (Radius 1) for 32° = .5585054
15′ = .0043633
27″ = .0001309
.5629996

.5629996 × 24.25 (length of radius) = 13.65274 feet.

DEGREES						MINUTES		SECONDS	
1°	.017 4533	61°	1.064 6508	121°	2.111 8484	1	.000 2909	1″	.000 0048
2	.034 9066	62	1.082 1041	122	2.129 3017	2	.000 5818	2	.000 0097
3	.052 3599	63	1.099 5574	123	2.146 7550	3	.000 8727	3	.000 0145
4	.069 8132	64	1.117 0107	124	2.164 2083	4	.001 1636	4	.000 0194
5	.087 2665	65	1.134 4640	125	2.181 6616	5	.001 4544	5	.000 0242
6	.104 7198	66	1.151 9173	126	2.199 1149	6	.001 7453	6	.000 0291
7	.122 1730	67	1.169 3706	127	2.216 5682	7	.002 0362	7	.000 0339
8	.139 6263	68	1.186 8239	128	2.234 0214	8	.002 3271	8	.000 0388
9	.157 0796	69	1.204 2772	129	2.251 4747	9	.002 6180	9	.000 0436
10	.174 5329	70	1.221 7305	130	2.268 9280	10	.002 9089	10	.000 0485
11	.191 9862	71	1.239 1838	131	2.286 3813	11	.003 1998	11	.000 0533
12	.209 4395	72	1.256 6371	132	2.303 8346	12	.003 4907	12	.000 0582
13	.226 8928	73	1.274 0904	133	2.321 2879	13	.003 7815	13	.000 0630
14	.244 3461	74	1.291 5436	134	2.338 7412	14	.004 0724	14	.000 0679
15	.261 7994	75	1.308 9969	135	2.356 1945	15	.004 3633	15	.000 0727
16	.279 2527	76	1.326 4502	136	2.373 6478	16	.004 6542	16	.000 0776
17	.296 7060	77	1.343 9035	137	2.391 1011	17	.004 9451	17	.000 0824
18	.314 1593	78	1.361 3568	138	2.408 5544	18	.005 2360	18	.000 0873
19	.331 6126	79	1.378 8101	139	2.426 0077	19	.005 5269	19	.000 0921
20	.349 0659	80	1.396 2634	140	2.443 4610	20	.005 8178	20	.000 0970
21	.366 5191	81	1.413 7167	141	2.460 9142	21	.006 1087	21	.000 1018
22	.383 9724	82	1.431 1700	142	2.478 3675	22	.006 3995	22	.000 1067
23	.401 4257	83	1.448 6233	143	2.495 8208	23	.006 6904	23	.000 1115
24	.418 8790	84	1.466 0766	144	2.513 2741	24	.006 9813	24	.000 1164
25	.436 3323	85	1.483 5299	145	2.530 7274	25	.007 2722	25	.000 1212
26	.453 7856	86	1.500 9832	146	2.548 1807	26	.007 5631	26	.000 1261
27	.471 2389	87	1.518 4364	147	2.565 6340	27	.007 8540	27	.000 1309
28	.488 6922	88	1.535 8897	148	2.583 0873	28	.008 1449	28	.000 1357
29	.506 1455	89	1.553 3430	149	2.600 5406	29	.008 4358	29	.000 1406
30	.523 5988	90	1.570 7963	150	2.617 9939	30	.008 7266	30	.000 1454
31	.541 0521	91	1.588 2496	151	2.635 4472	31	.009 0175	31	.000 1503
32	.558 5054	92	1.605 7029	152	2.652 9005	32	.009 3084	32	.000 1551
33	.575 9587	93	1.623 1562	153	2.670 3538	33	.009 5993	33	.000 1600
34	.593 4119	94	1.640 6095	154	2.687 8070	34	.009 8902	34	.000 1648
35	.610 8652	95	1.658 0628	155	2.705 2603	35	.010 1811	35	.000 1697
36	.628 3185	96	1.675 5161	156	2.722 7136	36	.010 4720	36	.000 1745
37	.645 7718	97	1.692 9694	157	2.740 1669	37	.010 7629	37	.000 1794
38	.663 2251	98	1.710 4227	158	2.757 6202	38	.011 0538	38	.000 1842
39	.680 6784	99	1.727 8760	159	2.775 0735	39	.011 3446	39	.000 1891
40	.698 1317	100	1.745 3293	160	2.792 5268	40	.011 6355	40	.000 1939
41	.715 5850	101	1.762 7825	161	2.809 9801	41	.011 9264	41	.000 1988
42	.733 0383	102	1.780 2358	162	2.827 4334	42	.012 2173	42	.000 2036
43	.750 4916	103	1.797 6891	163	2.844 8867	43	.012 5082	43	.000 2085
44	.767 9449	104	1.815 1424	164	2.862 3400	44	.012 7991	44	.000 2133
45	.785 3982	105	1.832 5957	165	2.879 7933	45	.013 0900	45	.000 2182
46	.802 8515	106	1.850 0490	166	2.897 2466	46	.013 3809	46	.000 2230
47	.820 3047	107	1.867 5023	167	2.914 6999	47	.013 6717	47	.000 2279
48	.837 7580	108	1.884 9556	168	2.932 1531	48	.013 9626	48	.000 2327
49	.855 2113	109	1.902 4089	169	2.949 6064	49	.014 2535	49	.000 2376
50	.872 6646	110	1.919 8622	170	2.967 0597	50	.014 5444	50	.000 2424
51	.890 1179	111	1.937 3155	171	2.984 5130	51	.014 8353	51	.000 2473
52	.907 5712	112	1.954 7688	172	3.001 9663	52	.015 1262	52	.000 2521
53	.925 0245	113	1.972 2221	173	3.019 4196	53	.015 4171	53	.000 2570
54	.942 4778	114	1.989 6753	174	3.036 8729	54	.015 7080	54	.000 2618
55	.959 9311	115	2.007 1286	175	3.054 3262	55	.015 9989	55	.000 2666
56	.977 3844	116	2.024 5819	176	3.071 7795	56	.016 2897	56	.000 2715
57	.994 8377	117	2.042 0352	177	3.089 2328	57	.016 5806	57	.000 2763
58	1.012 2910	118	2.059 4885	178	3.106 6861	58	.016 8715	58	.000 2812
59	1.029 7443	119	2.076 9418	179	3.124 1394	59	.017 1624	59	.000 2860
60	1.047 1976	120	2.094 3951	180	3.141 5927	60	.017 4533	60	.000 2909

VALUES FOR COMBINATIONS OF PI

$\pi = 3.14159265359 \quad \log_{10}\pi = 0.4971498726$

Combination	Values for n								
	1	2	3	4	5	6	7	8	9
$n\pi$	3.141593	6.283185	9.424778	12.566371	15.707963	18.849556	21.991149	25.132741	28.274334
$\frac{n\pi}{4}$	.785398	1.570796	2.356194	3.141593	3.926991	4.712389	5.497787	6.283185	7.068583
$\frac{n\pi}{6}$	.523599	1.047196	1.570796	2.094395	2.617994	3.141593	3.665191	4.188790	4.712389
$\frac{n\pi}{8}$	.392699	.785398	1.178097	1.570796	1.963495	2.356194	2.748894	3.141593	3.534292
$\frac{n\pi}{16}$	.196350	.392699	.589049	.785398	.981748	1.178097	1.374447	1.570796	1.767146
$\frac{n\pi}{32}$	.098175	1.96350	.294524	.392699	.490874	.589049	.687223	.785398	.883573
$\frac{n\pi}{64}$	.049087	.098175	.147262	.196350	.245437	.294524	.343612	.392699	.441786
$\frac{\pi}{n}$	3.141593	1.570796	1.047198	.785398	.628319	.523599	.448799	.392699	.349066
$\frac{n}{\pi}$	.318310	.636620	.954930	1.273240	1.591549	1.909859	2.228169	2.546479	2.864789
$\frac{\pi}{n\,90^\circ}$	.034907	.017453	.011636	.008727	.006981	.005818	.004987	.004363	.003879
$\frac{n\,90^\circ}{\pi}$	28.647890	57.295780	85.943670	114.59156	143.239450	171.88738	200.53523	229.18312	257.84101
π^n	3.141593	9.869604	31.006277	97.409091	306.01979	961.38937	3020.1938	9488.5331	29809.108
$\frac{1}{\pi^n}$	.318310	.101321	.032252	.010266	.003268	.001040	.000331	.000105	.000034
$\sqrt[n]{\pi}$	3.141593	1.772454	1.464592	1.331335	1.257274	1.210203	1.177664	1.153835	1.136635
$\frac{1}{\sqrt[n]{\pi}}$	.318310	.564190	.682784	.751126	.795371	.826307	.849139	.866675	.880564
$n\pi^2$	9.869604	19.739209	29.608813	39.478418	49.348022	59.217626	69.087231	79.956835	88.826440
$\frac{n}{\pi^2}$	.101321	.202642	.303963	.405284	.506605	.607926	.709247	.810568	.911889
$\sqrt{n\pi}$	1.772454	2.506628	3.069980	3.544908	3.963328	4.341608	4.689471	5.013257	5.317362
$\sqrt{\frac{n}{\pi}}$	.564190	.797885	.977205	1.128379	1.261566	1.381977	1.492705	1.595769	1.692569
$n\sqrt{\pi}$	1.772454	3.544908	5.317362	7.089815	8.862269	10.634723	12.407177	14.179631	15.952085
$\frac{n}{\sqrt{\pi}}$	.564190	1.128379	1.692569	2.256785	2.820948	3.385138	3.949327	4.513517	5.077706
$n\pi^3$	31.006277	62.012553	93.018830	124.02511	155.03138	186.03766	217.04394	248.05021	279.05649
$\frac{n}{\pi^3}$	.032252	.064503	.096755	.129006	.161258	.193509	.225761	.258012	.290264
$\sqrt[3]{n\pi}$	1.464592	1.845270	2.112469	2.324895	2.504417	2.661340	2.801663	2.929184	3.046474
$\sqrt[3]{\frac{n}{\pi}}$	.682784	.860254	.984745	1.086351	1.167544	1.240701	1.306189	1.365568	1.420248
$n\sqrt[3]{\pi}$	1.464592	2.929184	4.393776	5.858368	7.322959	8.787551	10.252143	11.716735	13.181327
$\frac{n}{\sqrt[3]{\pi}}$	.6827841	1.3655681	2.0483522	2.7311363	3.4139203	4.096704	4.779489	5.462273	6.145057
$n\pi^4$	97.409091	194.81818	292.22727	389.63636	487.04545	584.45455	681.86364	779.27273	876.68182
$\frac{n}{\pi^4}$	.0102660	.0205320	.0307979	.0410639	.0513299	.061596	.071862	.082128	.092394
$\sqrt[4]{n\pi}$	1.331335	1.583233	1.752136	1.882793	1.990811	2.083653	2.165519	2.239030	2.305940
$\sqrt[4]{\frac{n}{\pi}}$	.751126	.893244	.988537	1.062252	1.123195	1.175575	1.221763	1.263237	1.300988

More accurate values frequently used:

$\frac{\pi}{180} = 0.01745329252$, $\log\frac{\pi}{180} = 8.2418773675 - 10$, $\sqrt{\pi} = 1.772453851$, $\log\sqrt{\pi} = .2485749363$

$\frac{180}{\pi} = 57.29577949$, $\log\frac{180}{\pi} = 1.7581226325$, $\sqrt{\frac{1}{\pi}} = 0.5641895835$, $\log\sqrt{\frac{1}{\pi}} = 9.7514250637 - 10$

TRIGONOMETRIC FORMULAS

$$\sin A = \frac{1}{\operatorname{cosec} A} = \sqrt{1-\cos^2 A} = \tan A \cos A = 2 \sin \tfrac{1}{2} A \cos \tfrac{1}{2} A$$

$$= \operatorname{vers} A \cot \tfrac{1}{2} A = \sqrt{\tfrac{1}{2} \operatorname{vers} 2A} = \sqrt{\tfrac{1}{2}(1-\cos 2A)}$$

$$\cos A = \frac{1}{\sec A} = \sqrt{1-\sin^2 A} = \cot A \sin A = 1-\operatorname{vers} A = 2\cos^2 \tfrac{1}{2} A - 1$$

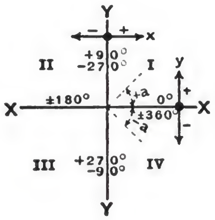
$$= 1-2\sin^2 \tfrac{1}{2} A = \cos^2 \tfrac{1}{2} A - \sin^2 \tfrac{1}{2} A = \sqrt{\tfrac{1}{2}+\tfrac{1}{2}\cos 2A}$$

$$\tan A = \frac{1}{\cot A} = \frac{\sin A}{\cos A} = \sqrt{\sec^2 A - 1} = \sqrt{\frac{1}{\cos^2 A} - 1} = \frac{\sqrt{1-\cos^2 A}}{\cos A}$$

$$= \frac{\sin 2A}{1+\cos 2A} = \frac{1-\cos 2A}{\sin 2A} = \frac{\operatorname{vers} 2A}{\sin 2A} = \operatorname{exsec} A \cot \tfrac{1}{2} A$$

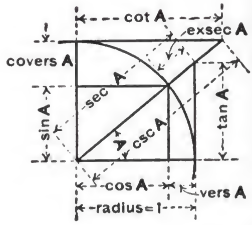
$$\cot A = \frac{1}{\tan A} = \frac{\cos A}{\sin A} = \sqrt{\operatorname{cosec}^2 A - 1} = \frac{\sin 2A}{1-\cos 2A} = \frac{\sin 2A}{\operatorname{vers} 2A}$$

$$= \frac{1+\cos 2A}{\sin 2A} = \frac{\tan \tfrac{1}{2} A}{\operatorname{exsec} A}$$



$$\operatorname{vers} A = 1-\cos A = \sin A \tan \tfrac{1}{2} A = 2\sin^2 \tfrac{1}{2} A = \operatorname{exsec} A \cos A$$

$$\operatorname{exsec} A = \sec A - 1 = \tan A \tan \tfrac{1}{2} A = \frac{\operatorname{vers} A}{\cos A}$$



$$\sin \tfrac{1}{2} A = \sqrt{\frac{1-\cos A}{2}} = \sqrt{\frac{\operatorname{vers} A}{2}} \qquad \cos \tfrac{1}{2} A = \sqrt{\frac{1+\cos A}{2}}$$

$$\tan \tfrac{1}{2} A = \frac{\tan A}{1+\sec A} = \operatorname{cosec} A - \cot A = \frac{1-\cos A}{\sin A} = \sqrt{\frac{1-\cos A}{1+\cos A}}$$

$$\cot \tfrac{1}{2} A = \frac{\sin A}{\operatorname{vers} A} = \frac{1+\cos A}{\sin A} = \frac{1}{\operatorname{cosec} A - \cot A}$$

$$\operatorname{vers} \tfrac{1}{2} A = \frac{\tfrac{1}{2} \operatorname{vers} A}{1+\sqrt{1-\tfrac{1}{2}\operatorname{vers} A}} = \frac{1-\cos A}{2+\sqrt{2(1+\cos A)}}$$

$$\operatorname{exsec} \tfrac{1}{2} A = \frac{1-\cos A}{(1+\cos A)+\sqrt{2(1+\cos A)}} \qquad \sin 2A = 2\sin A \cos A$$

$$\cos 2A = 2\cos^2 A - 1 = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A$$

$$\tan 2A = \frac{2\tan A}{1-\tan^2 A} \qquad \cot 2A = \frac{\cot^2 A - 1}{2\cot A}$$

$$\operatorname{vers} 2A = 2\sin^2 A = 2\sin A \cos A \tan A$$

$$\operatorname{exsec} 2A = \frac{2\tan^2 A}{1-\tan^2 A}$$

$$\sin 3A = 3\sin A - 4\sin^3 A$$

$$\cos 3A = 4\cos^3 A - 3\cos A$$

$$\tan 3A = \frac{3\tan A - \tan^3 A}{1-3\tan^2 A}$$

$$\sin 4A = 4\sin A \cos A - 8\sin^3 A \cos A$$

$$\cos 4A = 1 - 8\cos^2 A + 8\cos^4 A$$

$$\tan 4A = \frac{4\tan A - 4\tan^3 A}{1-6\tan^2 A + \tan^4 A}$$

$$\sin(A+B) = \sin A \cos B + \sin B \cos A$$

$$\sin(A-B) = \sin A \cos B - \sin B \cos A$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\cos(A-B) = \cos A \cos B + \sin A \sin B$$

$$\sin A + \sin B = 2\sin \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$

$$\sin A - \sin B = 2\cos \tfrac{1}{2}(A+B) \sin \tfrac{1}{2}(A-B)$$

$$\cos A + \cos B = 2\cos \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$

$$\cos B - \cos A = 2\sin \tfrac{1}{2}(A+B) \sin \tfrac{1}{2}(A-B)$$

$$\sin^2 A - \sin^2 B = \cos^2 B - \cos^2 A = \sin(A+B)\sin(A-B)$$

$$\cos^2 A - \sin^2 B = \cos(A+B)\cos(A-B)$$

$$\tan A + \tan B = \frac{\sin(A+B)}{\cos A \cos B}$$

$$\tan A - \tan B = \frac{\sin(A-B)}{\cos A \cos B}$$

Range of Function Values

Quadrant		I	II	III	IV
Angles	+	0°- 90°	90°-180°	180°-270°	270°-360°
	−	270°-360°	180°-270°	90°-180°	0°- 90°
sin	+A	0 to +1	+1 to 0	0 to −1	−1 to 0
	−A	+1 to 0	0 to +1	−1 to 0	0 to −1
cos	+A	+1 to 0	0 to −1	−1 to 0	0 to +1
	−A	0 to +1	−1 to 0	0 to −1	+1 to 0
tan	+A	0 to +∞	−∞ to 0	0 to +∞	−∞ to 0
	−A	+∞ to 0	0 to −∞	+∞ to 0	0 to −∞
cot	+A	+∞ to 0	0 to −∞	+∞ to 0	0 to −∞
	−A	0 to +∞	−∞ to 0	0 to +∞	−∞ to 0

Functions of Angles Greater than 90°

Angle A	sin A	cos A	tan A	cot A
0° ± a	± sin a	+ cos a	± tan a	± cot a
90° ± a	+ cos a	∓ sin a	∓ cot a	∓ tan a
180° ± a	∓ sin a	− cos a	± tan a	± cot a
270° ± a	− cos a	± sin a	∓ cot a	∓ tan a
360° ± a	± sin a	+ cos a	± tan a	± cot a

NATURAL TRIGONOMETRIC FUNCTIONS

Degrees	SINES							Cosines
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01454	0.01745	89
1	0.01745	0.02036	0.02327	0.02618	0.02908	0.03199	0.03490	88
2	0.03490	0.03781	0.04071	0.04362	0.04653	0.04943	0.05234	87
3	0.05234	0.05524	0.05814	0.06105	0.06395	0.06685	0.06976	86
4	0.06976	0.07266	0.07556	0.07846	0.08136	0.08426	0.08716	85
5	0.08716	0.09005	0.09295	0.09585	0.09874	0.10164	0.10453	84
6	0.10453	0.10742	0.11031	0.11320	0.11609	0.11898	0.12187	83
7	0.12187	0.12476	0.12764	0.13053	0.13341	0.13629	0.13917	82
8	0.13917	0.14205	0.14493	0.14781	0.15069	0.15356	0.15643	81
9	0.15643	0.15931	0.16218	0.16505	0.16792	0.17078	0.17365	80
10	0.17365	0.17651	0.17937	0.18224	0.18509	0.18795	0.19081	79
11	0.19081	0.19366	0.19652	0.19937	0.20222	0.20507	0.20791	78
12	0.20791	0.21076	0.21360	0.21644	0.21928	0.22212	0.22495	77
13	0.22495	0.22778	0.23062	0.23345	0.23627	0.23910	0.24192	76
14	0.24192	0.24474	0.24756	0.25038	0.25320	0.25601	0.25882	75
15	0.25882	0.26163	0.26443	0.26724	0.27004	0.27284	0.27564	74
16	0.27564	0.27843	0.28123	0.28402	0.28680	0.28959	0.29237	73
17	0.29237	0.29515	0.29793	0.30071	0.30348	0.30625	0.30902	72
18	0.30902	0.31178	0.31454	0.31730	0.32006	0.32282	0.32557	71
19	0.32557	0.32832	0.33106	0.33381	0.33655	0.33929	0.34202	70
20	0.34202	0.34475	0.34748	0.35021	0.35293	0.35565	0.35837	69
21	0.35837	0.36108	0.36379	0.36650	0.36921	0.37191	0.37461	68
22	0.37461	0.37730	0.37999	0.38268	0.38537	0.38805	0.39073	67
23	0.39073	0.39341	0.39608	0.39875	0.40142	0.40408	0.40674	66
24	0.40674	0.40939	0.41204	0.41469	0.41734	0.41998	0.42262	65
25	0.42262	0.42525	0.42788	0.43051	0.43313	0.43575	0.43837	64
26	0.43837	0.44098	0.44359	0.44620	0.44880	0.45140	0.45399	63
27	0.45399	0.45658	0.45917	0.46175	0.46433	0.46690	0.46947	62
28	0.46947	0.47204	0.47460	0.47716	0.47971	0.48226	0.48481	61
29	0.48481	0.48735	0.48989	0.49242	0.49495	0.49748	0.50000	60
30	0.50000	0.50252	0.50503	0.50754	0.51004	0.51254	0.51504	59
31	0.51504	0.51753	0.52002	0.52250	0.52498	0.52745	0.52992	58
32	0.52992	0.53238	0.53484	0.53730	0.53975	0.54220	0.54464	57
33	0.54464	0.54708	0.54951	0.55194	0.55436	0.55678	0.55919	56
34	0.55919	0.56160	0.56401	0.56641	0.56880	0.57119	0.57358	55
35	0.57358	0.57596	0.57833	0.58070	0.58307	0.58543	0.58779	54
36	0.58779	0.59014	0.59248	0.59482	0.59716	0.59949	0.60182	53
37	0.60182	0.60414	0.60645	0.60876	0.61107	0.61337	0.61566	52
38	0.61566	0.61795	0.62024	0.62251	0.62479	0.62706	0.62932	51
39	0.62932	0.63158	0.63383	0.63608	0.63832	0.64056	0.64279	50
40	0.64279	0.64501	0.64723	0.64945	0.65166	0.65386	0.65606	49
41	0.65606	0.65825	0.66044	0.66262	0.66480	0.66697	0.66913	48
42	0.66913	0.67129	0.67344	0.67559	0.67773	0.67987	0.68200	47
43	0.68200	0.68412	0.68624	0.68835	0.69046	0,69256	0.69466	46
44	0.69466	0.69675	0.69883	0.70091	0.70298	0.70505	0.70711	45
	60′	50′	40′	30′	20′	10′	0′	
Sines	COSINES							Degrees

Degrees	COSINES							Sines
	0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00000	0.99998	0.99996	0.99993	0.99989	0.99985	89
1	0.99985	0.99979	0.99973	0.99966	0.99958	0.99949	0.99939	88
2	0.99939	0.99929	0.99917	0.99905	0.99892	0.99878	0.99863	87
3	0.99863	0.99847	0.99831	0.99813	0.99795	0.99776	0.99756	86
4	0.99756	0.99736	0.99714	0.99692	0.99668	0.99644	0.99619	85
5	0.99619	0.99594	0.99567	0.99540	0.99511	0.99482	0.99452	84
6	0.99452	0.99421	0.99390	0.99357	0.99324	0.99290	0.99255	83
7	0.99255	0.99219	0.99182	0.99144	0.99106	0.99067	0.99027	82
8	0.99027	0.98986	0.98944	0.98902	0.98858	0.98814	0.98769	81
9	0.98769	0.98723	0.98676	0.98629	0.98580	0.98531	0.98481	80
10	0.98481	0.98430	0.98378	0.98325	0.98272	0.98218	0.98163	79
11	0.98163	0.98107	0.98050	0.97992	0.97934	0.97875	0.97815	78
12	0.97815	0.97754	0.97692	0.97630	0.97566	0.97502	0.97437	77
13	0.97437	0.97371	0.97304	0.97237	0.97169	0.97100	0.97030	76
14	0.97030	0.96959	0.96887	0.96815	0.96742	0.96667	0.96593	75
15	0.96593	0.96517	0.96440	0.96363	0.96285	0.96206	0.96126	74
16	0.96126	0.96046	0.95964	0.95882	0.95799	0.95715	0.95630	73
17	0.95630	0.95545	0.95459	0.95372	0.95284	0.95195	0.95106	72
18	0.95106	0.95015	0.94924	0.94832	0.94740	0.94646	0.94552	71
19	0.94552	0.94457	0.94361	0.94264	0.94167	0.94068	0.93969	70
20	0.93969	0.93869	0.93769	0.93667	0.93565	0.93462	0.93358	69
21	0.93358	0.93253	0.93148	0.93042	0.92935	0.92827	0.92718	68
22	0.92718	0.92609	0.92499	0.92388	0.92276	0.92164	0.92050	67
23	0.92050	0.91936	0.91822	0.91706	0.91590	0.91472	0.91355	66
24	0.91355	0.91236	0.91116	0.90996	0.90875	0.90753	0.90631	65
25	0.90631	0.90507	0.90383	0.90259	0.90133	0.90007	0.89879	64
26	0.89879	0.89752	0.89623	0.89493	0.89363	0.89232	0.89101	63
27	0.89101	0.88968	0.88835	0.88701	0.88566	0.88431	0.88295	62
28	0.88295	0.88158	0.88020	0.87882	0.87743	0.87603	0.87462	61
29	0.87462	0.87321	0.87178	0.87036	0.86892	0.86748	0.86603	60
30	0.86603	0.86457	0.86310	0.86163	0.86015	0.85866	0.85717	59
31	0.85717	0.85567	0.85416	0.85264	0.85112	0.84959	0.84805	58
32	0.84805	0.84650	0.84495	0.84339	0.84182	0.84025	0.83867	57
33	0.83867	0.83708	0.83549	0.83389	0.83228	0.83066	0.82904	56
34	0.82904	0.82741	0.82577	0.82413	0.82248	0.82082	0.81915	55
35	0.81915	0.81748	0.81580	0.81412	0.81242	0.81072	0.80902	54
36	0.80902	0.80730	0.80558	0.80386	0.80212	0.80038	0.79864	53
37	0.79864	0.79688	0.79512	0.79335	0.79158	0.78980	0.78801	52
38	0.78801	0.78622	0.78442	0.78261	0.78079	0.77897	0.77715	51
39	0.77715	0.77531	0.77347	0.77162	0.76977	0.76791	0.76604	50
40	0.76604	0.76417	0.76229	0.76041	0.75851	0.75661	0.75471	49
41	0.75471	0.75280	0.75088	0.74896	0.74703	0.74509	0.74314	48
42	0.74314	0.74120	0.73924	0.73728	0.73531	0.73333	0.73135	47
43	0.73135	0.72937	0.72737	0.72537	0.72337	0.72136	0.71934	46
44	0.71934	0.71732	0.71529	0.71325	0.71121	0.70916	0.70711	45
Cosines	60′	50′	40′	30′	20′	10′	0′	Degrees
	SINES							

Degrees	TANGENTS							Cotangents
	0′	10′	20′	30′	40′	50′	60′	
0	0.00000	0.00291	0.00582	0.00873	0.01164	0.01455	0.01746	89
1	0.01746	0.02036	0.02328	0.02619	0.02910	0.03201	0.03492	88
2	0.03492	0.03783	0.04075	0.04366	0.04658	0.04949	0.05241	87
3	0.05241	0.05533	0.05824	0.06116	0.06408	0.06700	0.06993	86
4	0.06993	0.07285	0.07578	0.07870	0.08163	0.08456	0.08749	85
5	0.08749	0.09042	0.09335	0.09629	0.09923	0.10216	0.10510	84
6	0.10510	0.10805	0.11099	0.11394	0.11688	0.11983	0.12278	83
7	0.12278	0.12574	0.12869	0.13165	0.13461	0.13758	0.14054	82
8	0.14054	0.14351	0.14648	0.14945	0.15243	0.15540	0.15838	81
9	0.15838	0.16137	0.16435	0.16734	0.17033	0.17333	0.17633	80
10	0.17633	0.17933	0.18233	0.18534	0.18835	0.19136	0.19438	79
11	0.19438	0.19740	0.20042	0.20345	0.20648	0.20952	0.21256	78
12	0.21256	0.21560	0.21864	0.22169	0.22475	0.22781	0.23087	77
13	0.23087	0.23393	0.23700	0.24008	0.24316	0.24624	0.24933	76
14	0.24933	0.25242	0.25552	0.25862	0.26172	0.26483	0.26795	75
15	0.26795	0.27107	0.27419	0.27732	0.28046	0.28360	0.28675	74
16	0.28675	0.28990	0.29305	0.29621	0.29938	0.30255	0.30573	73
17	0.30573	0.30891	0.31210	0.31530	0.31850	0.32171	0.32492	72
18	0.32492	0.32814	0.33136	0.33460	0.33783	0.34108	0.34433	71
19	0.34433	0.34758	0.35085	0.35412	0.35740	0.36068	0.36397	70
20	0.36397	0.36727	0.37057	0.37388	0.37720	0.38053	0.38386	69
21	0.38386	0.38721	0.39055	0.39391	0.39727	0.40065	0.40403	68
22	0.40403	0.40741	0.41081	0.41421	0.41763	0.42105	0.42447	67
23	0.42447	0.42791	0.43136	0.43481	0.43828	0.44175	0.44523	66
24	0.44523	0.44872	0.45222	0.45573	0.45924	0.46277	0.46631	65
25	0.46631	0.46985	0.47341	0.47698	0.48055	0.48414	0.48773	64
26	0.48773	0.49134	0.49495	0.49858	0.50222	0.50587	0.50953	63
27	0.50953	0.51320	0.51688	0.52057	0.52427	0.52798	0.53171	62
28	0.53171	0.53545	0.53920	0.54296	0.54674	0.55051	0.55431	61
29	0.55431	0.55812	0.56194	0.56577	0.56962	0.57348	0.57735	60
30	0.57735	0.58124	0.58513	0.58905	0.59297	0.59691	0.60086	59
31	0.60086	0.60483	0.60881	0.61280	0.61681	0.62083	0.62487	58
32	0.62487	0.62892	0.63299	0.63707	0.64117	0.64528	0.64941	57
33	0.64941	0.65355	0.65771	0.66189	0.66608	0.67028	0.67451	56
34	0.67451	0.67875	0.68301	0.68728	0.69157	0.69588	0.70021	55
35	0.70021	0.70455	0.70891	0.71329	0.71769	0.72211	0.72654	54
36	0.72654	0.73100	0.73547	0.73996	0.74447	0.74900	0.75355	53
37	0.75355	0.75812	0.76272	0.76733	0.77196	0.77661	0.78129	52
38	0.78129	0.78598	0.79070	0.79544	0.80020	0.80498	0.80978	51
39	0.80978	0.81461	0.81946	0.82434	0.82923	0.83415	0.83910	50
40	0.83910	0.84407	0.84906	0.85408	0.85912	0.86419	0.86929	49
41	0.86929	0.87441	0.87955	0.88473	0.88992	0.89515	0.90040	48
42	0.90040	0.90569	0.91099	0.91633	0.92170	0.92709	0.93252	47
43	0.93252	0.93797	0.94345	0.94896	0.95451	0.96008	0.96569	46
44	0.96569	0.97133	0.97700	0.98270	0.98843	0.99420	1.00000	45
Tangents	60′	50′	40′	30′	20′	10′	0′	Degrees
	COTANGENTS							

Degrees	COTANGENTS							Tangents
	0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77371	171.88540	114.58865	85.93979	68.75009	57.28996	89
1	57.28996	49.10388	42.96408	38.18846	34.36777	31.24158	28.63625	88
2	28.63625	26.43160	24.54176	22.90377	21.47040	20.20555	19.08114	87
3	19.08114	18.07498	17.16934	16.34986	15.60478	14.92442	14.30067	86
4	14.30067	13.72674	13.19688	12.70621	12.25051	11.82617	11.43005	85
5	11.43005	11.05943	10.71191	10.38540	10.07803	9.78817	9.51436	84
6	9.51436	9.25530	9.00983	8.77689	8.55555	8.34496	8.14435	83
7	8.14435	7.95302	7.77035	7.59575	7.42871	7.26873	7.11537	82
8	7.11537	6.96823	6.82694	6.69116	6.56055	6.43484	6.31375	81
9	6.31375	6.19703	6.08444	5.97576	5.87080	5.76937	5.67128	80
10	5.67128	5.57638	5.48451	5.39552	5.30928	5.22566	5.14455	79
11	5.14455	5.06584	4.98940	4.91516	4.84300	4.77286	4.70463	78
12	4.70463	4.63825	4.57363	4.51071	4.44942	4.38969	4.33148	77
13	4.33148	4.27471	4.21933	4.16530	4.11256	4.06107	4.01078	76
14	4.01078	3.96165	3.91364	3.86671	3.82083	3.77595	3.73205	75
15	3.73205	3.68909	3.64705	3.60588	3.56557	3.52609	3.48741	74
16	3.48741	3.44951	3.41236	3.37594	3.34023	3.30521	3.27085	73
17	3.27085	3.23714	3.20406	3.17159	3.13972	3.10842	3.07768	72
18	3.07768	3.04749	3.01783	2.98869	2.96004	2.93189	2.90421	71
19	2.90421	2.87700	2.85023	2.82391	2.79802	2.77254	2.74748	70
20	2.74748	2.72281	2.69853	2.67462	2.65109	2.62791	2.60509	69
21	2.60509	2.58261	2.56046	2.53865	2.51715	2.49597	2.47509	68
22	2.47509	2.45451	2.43422	2.41421	2.39449	2.37504	2.35585	67
23	2.35585	2.33693	2.31826	2.29984	2.28167	2.26374	2.24604	66
24	2.24604	2.22857	2.21132	2.19430	2.17749	2.16090	2.14451	65
25	2.14451	2.12832	2.11233	2.09654	2.08094	2.06553	2.05030	64
26	2.05030	2.03526	2.02039	2.00569	1.99116	1.97680	1.96261	63
27	1.96261	1.94858	1.93470	1.92098	1.90741	1.89400	1.88073	62
28	1.88073	1.86760	1.85462	1.84177	1.82907	1.81649	1.80405	61
29	1.80405	1.79174	1.77955	1.76749	1.75556	1.74375	1.73205	60
30	1.73205	1.72047	1.70901	1.69766	1.68643	1.67530	1.66428	59
31	1.66428	1.65337	1.64256	1.63185	1.62125	1.61074	1.60033	58
32	1.60033	1.59002	1.57981	1.56969	1.55966	1.54972	1.53987	57
33	1.53987	1.53010	1.52043	1.51084	1.50133	1.49190	1.48256	56
34	1.48256	1.47330	1.46411	1.45501	1.44598	1.43703	1.42815	55
35	1.42815	1.41934	1.41061	1.40195	1.39336	1.38484	1.37638	54
36	1.37638	1.36800	1.35968	1.35142	1.34323	1.33511	1.32704	53
37	1.32704	1.31904	1.31110	1.30323	1.29541	1.28764	1.27994	52
38	1.27994	1.27230	1.26471	1.25717	1.24969	1.24227	1.23490	51
39	1.23490	1.22758	1.22031	1.21310	1.20593	1.19882	1.19175	50
40	1.19175	1.18474	1.17777	1.17085	1.16398	1.15715	1.15037	49
41	1.15037	1.14363	1.13694	1.13029	1.12369	1.11713	1.11061	48
42	1.11061	1.10414	1.09770	1.09131	1.08496	1.07864	1.07237	47
43	1.07237	1.06613	1.05994	1.05378	1.04766	1.04158	1.03553	46
44	1.03553	1.02952	1.02355	1.01761	1.01170	1.00583	1.00000	45
Cotangents	60′	50′	40′	30′	20′	10′	0′	Degrees
	TANGENTS							

Degrees	SECANTS							Cosecants
	0′	10′	20′	30′	40′	50′	60′	
0	1.00000	1.00000	1.00002	1.00004	1.00007	1.00011	1.00015	89
1	1.00015	1.00021	1.00027	1.00034	1.00042	1.00051	1.00061	88
2	1.00061	1.00072	1.00083	1.00095	1.00108	1.00122	1.00137	87
3	1.00137	1.00153	1.00169	1.00187	1.00205	1.00224	1.00244	86
4	1.00244	1.00265	1.00287	1.00309	1.00333	1.00357	1.00382	85
5	1.00382	1.00408	1.00435	1.00463	1.00491	1.00521	1.00551	84
6	1.00551	1.00582	1.00614	1.00647	1.00681	1.00715	1.00751	83
7	1.00751	1.00787	1.00825	1.00863	1.00902	1.00942	1.00983	82
8	1.00983	1.01024	1.01067	1.01111	1.01155	1.01200	1.01247	81
9	1.01247	1.01294	1.01342	1.01391	1.01440	1.01491	1.01543	80
10	1.01543	1.01595	1.01649	1.01703	1.01758	1.01815	1.01872	79
11	1.01872	1.01930	1.01989	1.02049	1.02110	1.02171	1.02234	78
12	1.02234	1.02298	1.02362	1.02428	1.02494	1.02562	1.02630	77
13	1.02630	1.02700	1.02770	1.02842	1.02914	1.02987	1.03061	76
14	1.03061	1.03137	1.03213	1.03290	1.03368	1.03447	1.03528	75
15	1.03528	1.03609	1.03691	1.03774	1.03858	1.03944	1.04030	74
16	1.04030	1.04117	1.04206	1.04295	1.04385	1.04477	1.04569	73
17	1.04569	1.04663	1.04757	1.04853	1.04950	1.05047	1.05146	72
18	1.05146	1.05246	1.05347	1.05449	1.05552	1.05657	1.05762	71
19	1.05762	1.05869	1.05976	1.06085	1.06195	1.06306	1.06418	70
20	1.06418	1.06531	1.06645	1.06761	1.06878	1.06995	1.07115	69
21	1.07115	1.07235	1.07356	1.07479	1.07602	1.07727	1.07853	68
22	1.07853	1.07981	1.08109	1.08239	1.08370	1.08503	1.08636	67
23	1.08636	1.08771	1.08907	1.09044	1.09183	1.09323	1.09464	66
24	1.09464	1.09606	1.09750	1.09895	1.10041	1.10189	1.10338	65
25	1.10338	1.10488	1.10640	1.10793	1.10947	1.11103	1.11260	64
26	1.11260	1.11419	1.11579	1.11740	1.11903	1.12067	1.12233	63
27	1.12233	1.12400	1.12568	1.12738	1.12910	1.13083	1.13257	62
28	1.13257	1.13433	1.13610	1.13789	1.13970	1.14152	1.14335	61
29	1.14335	1.14521	1.14707	1.14896	1.15085	1.15277	1.15470	60
30	1.15470	1.15665	1.15861	1.16059	1.16259	1.16460	1.16663	59
31	1.16663	1.16868	1.17075	1.17283	1.17493	1.17704	1.17918	58
32	1.17918	1.18133	1.18350	1.18569	1.18790	1.19012	1.19236	57
33	1.19236	1.19463	1.19691	1.19920	1.20152	1.20386	1.20622	56
34	1.20622	1.20859	1.21099	1.21341	1.21584	1.21830	1.22077	55
35	1.22077	1.22327	1.22579	1.22833	1.23089	1.23347	1.23607	54
36	1.23607	1.23869	1.24134	1.24400	1.24669	1.24940	1.25214	53
37	1.25214	1.25489	1.25767	1.26047	1.26330	1.26615	1.26902	52
38	1.26902	1.27191	1.27483	1.27778	1.28075	1.28374	1.28676	51
39	1.28676	1.28980	1.29287	1.29597	1.29909	1.30223	1.30541	50
40	1.30541	1.30861	1.31183	1.31509	1.31837	1.32168	1.32501	49
41	1.32501	1.32838	1.33177	1.33519	1.33864	1.34212	1.34563	48
42	1.34563	1.34917	1.35274	1.35634	1.35997	1.36363	1.36733	47
43	1.36733	1.37105	1.37481	1.37860	1.38242	1.38628	1.39016	46
44	1.39016	1.39409	1.39804	1.40203	1.40606	1.41012	1.41421	45
Secants	60′	50′	40′	30′	20′	10′	0′	Degrees
	COSECANTS							

Degrees	COSECANTS							Secants
	0′	10′	20′	30′	40′	50′	60′	
0	∞	343.77516	171.88831	114.59301	85.94561	68.75736	57.29869	89
1	57.29869	49.11406	42.97571	38.20155	34.38232	31.25758	28.65371	88
2	28.65371	26.45051	24.56212	22.92559	21.49368	20.23028	19.10732	87
3	19.10732	18.10262	17.19843	16.38041	15.63679	14.95788	14.33559	86
4	14.33559	13.76312	13.23472	12.74550	12.29125	11.86837	11.47371	85
5	11.47371	11.10455	10.75849	10.43343	10.12752	9.83912	9.56677	84
6	9.56677	9.30917	9.06515	8.83367	8.61379	8.40466	8.20551	83
7	8.20551	8.01565	7.83443	7.66130	7.49571	7.33719	7.18530	82
8	7.18530	7.03962	6.89979	6.76547	6.63633	6.51208	6.39245	81
9	6.39245	6.27719	6.16607	6.05886	5.95536	5.85539	5.75877	80
10	5.75877	5.66533	5.57493	5.48740	5.40263	5.32049	5.24084	79
11	5.24084	5.16359	5.08863	5.01585	4.94517	4.87649	4.80973	78
12	4.80973	4.74482	4.68167	4.62023	4.56041	4.50216	4.44541	77
13	4.44541	4.39012	4.33622	4.28366	4.23239	4.18238	4.13357	76
14	4.13357	4.08591	4.03938	3.99393	3.94952	3.90613	3.86370	75
15	3.86370	3.82223	3.78166	3.74198	3.70315	3.66515	3.62796	74
16	3.62796	3.59154	3.55587	3.52094	3.48671	3.45317	3.42030	73
17	3.42030	3.38808	3.35649	3.32551	3.29512	3.26531	3.23607	72
18	3.23607	3.20737	3.17920	3.15155	3.12440	3.09774	3.07155	71
19	3.07155	3.04584	3.02057	2.99574	2.97135	2.94737	2.92380	70
20	2.92380	2.90063	2.87785	2.85545	2.83342	2.81175	2.79043	69
21	2.79043	2.76945	2.74881	2.72850	2.70851	2.68884	2.66947	68
22	2.66947	2.65040	2.63162	2.61313	2.59491	2.57698	2.55930	67
23	2.55930	2.54190	2.52474	2.50784	2.49119	2.47477	2.45859	66
24	2.45859	2.44264	2.42692	2.41142	2.39614	2.38107	2.36620	65
25	2.36620	2.35154	2.33708	2.32282	2.30875	2.29487	2.28117	64
26	2.28117	2.26766	2.25432	2.24116	2.22817	2.21535	2.20269	63
27	2.20269	2.19019	2.17786	2.16568	2.15366	2.14178	2.13005	62
28	2.13005	2.11847	2.10704	2.09574	2.08458	2.07356	2.06267	61
29	2.06267	2.05191	2.04128	2.03077	2.02039	2.01014	2.00000	60
30	2.00000	1.98998	1.98008	1.97029	1.96062	1.95106	1.94160	59
31	1.94160	1.93226	1.92302	1.91388	1.90485	1.89591	1.88709	58
32	1.88708	1.87834	1.86970	1.86116	1.85271	1.84435	1.83608	57
33	1.83608	1.82790	1.81981	1.81180	1.80388	1.79604	1.78829	56
34	1.78829	1.78062	1.77303	1.76552	1.75808	1.75073	1.74345	55
35	1.74345	1.73624	1.72911	1.72205	1.71506	1.70815	1.70130	54
36	1.70130	1.69452	1.68782	1.68117	1.67460	1.66809	1.66164	53
37	1.66164	1.65526	1.64894	1.64268	1.63648	1.63035	1.62427	52
38	1.62427	1.61825	1.61229	1.60639	1.60054	1.59475	1.58902	51
39	1.58902	1.58333	1.57771	1.57213	1.56661	1.56114	1.55572	50
40	1.55572	1.55036	1.54504	1.53977	1.53455	1.52938	1.52425	49
41	1.52425	1.51918	1.51415	1.50916	1.50422	1.49933	1.49448	48
42	1.49448	1.48967	1.48491	1.48019	1.47551	1.47087	1.46628	47
43	1.46628	1.46173	1.45721	1.45274	1.44831	1.44391	1.43956	46
44	1.43956	1.43524	1.43096	1.42672	1.42251	1.41835	1.41421	45
Cosecants	60′	50′	40′	30′	20′	10′	0′	Degrees
	SECANTS							

LOGARITHMS OF NUMBERS

100–150 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
100	00 000	043	087	130	173	217	260	303	346	389
101	432	475	518	561	604	647	689	732	775	817
102	00 860	903	945	988	*030	*072	*115	*157	*199	*242
103	01 284	326	368	410	452	494	536	578	620	662
104	01 703	745	787	828	870	912	953	995	*036	*078
105	02 119	160	202	243	284	325	366	407	449	490
106	531	572	612	653	694	735	776	816	857	898
107	02 938	979	*019	*060	*100	*141	*181	*222	*262	*302
108	03 342	383	423	463	503	543	583	623	663	703
109	03 743	782	822	862	902	941	981	*021	*060	*100
110	04 139	179	218	258	297	336	376	415	454	493
111	532	571	610	650	689	727	766	805	844	883
112	04 922	961	999	*038	*077	*115	*154	*192	*231	*269
113	05 308	346	385	423	461	500	538	576	614	652
114	05 690	729	767	805	843	881	918	956	994	*032
115	06 070	108	145	183	221	258	296	333	371	408
116	446	483	521	558	595	633	670	707	744	781
117	06 819	856	893	930	967	*004	*041	*078	*115	*151
118	07 188	225	262	298	335	372	408	445	482	518
119	555	591	628	664	700	737	773	809	846	882
120	07 918	954	990	*027	*063	*099	*135	*171	*207	*243
121	08 279	314	350	386	422	458	493	529	565	600
122	636	672	707	743	778	814	849	884	920	955
123	08 991	*026	*061	*096	*132	*167	*202	*237	*272	*307
124	09 342	377	412	447	482	517	552	587	621	656
125	09 691	726	760	795	830	864	899	934	968	*003
126	10 037	072	106	140	175	209	243	278	312	346
127	380	415	449	483	517	551	585	619	653	687
128	10 721	755	789	823	857	890	924	958	992	*025
129	11 059	093	126	160	193	227	261	294	327	361
130	11 394	428	461	494	528	561	594	628	661	694
131	11 727	760	793	826	860	893	926	959	992	*024
132	12 057	090	123	156	189	222	254	287	320	352
133	385	418	450	483	516	548	581	613	646	678
134	12 710	743	775	808	840	872	905	937	969	*001
135	13 033	066	098	130	162	194	226	258	290	322
136	354	386	418	450	481	513	545	577	609	640
137	672	704	735	767	799	830	862	893	925	956
138	13 988	*019	*051	*082	*114	*145	*176	*208	*239	*270
139	14 301	333	364	395	426	457	489	520	551	582
140	14 613	644	675	706	737	768	799	829	860	891
141	14 922	953	983	*014	*045	*076	*106	*137	*168	*198
142	15 229	259	290	320	351	381	412	442	473	503
143	534	564	594	625	655	685	715	746	776	806
144	15 836	866	897	927	957	987	*017	*047	*077	*107
145	16 137	167	197	227	256	286	316	346	376	406
146	435	465	495	524	554	584	613	643	673	702
147	16 732	761	791	820	850	879	909	938	967	997
148	17 026	056	085	114	143	173	202	231	260	289
149	319	348	377	406	435	464	493	522	551	580
150	17 609	638	667	696	725	754	782	811	840	869
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	44	43	42
1	4.4	4.3	4.2
2	8.8	8.6	8.4
3	13.2	12.9	12.6
4	17.6	17.2	16.8
5	22.0	21.5	21.0
6	26.4	25.8	25.2
7	30.8	30.1	29.4
8	35.2	34.4	33.6
9	39.6	38.7	37.8

n \ d	41	40	39
1	4.1	4	3.9
2	8.2	8	7.8
3	12.3	12	11.7
4	16.4	16	15.6
5	20.5	20	19.5
6	24.6	24	23.4
7	28.7	28	27.3
8	32.8	32	31.2
9	36.9	36	35.1

n \ d	38	37	36
1	3.8	3.7	3.6
2	7.6	7.4	7.2
3	11.4	11.1	10.8
4	15.2	14.8	14.4
5	19.0	18.5	18.0
6	22.8	22.2	21.6
7	26.6	25.9	25.2
8	30.4	29.6	28.8
9	34.2	33.3	32.4

n \ d	35	34	33
1	3.5	3.4	3.3
2	7.0	6.8	6.6
3	10.5	10.2	9.9
4	14.0	13.6	13.2
5	17.5	17.0	16.5
6	21.0	20.4	19.8
7	24.5	23.8	23.1
8	28.0	27.2	26.4
9	31.5	30.6	29.7

n \ d	32	31	30
1	3.2	3.1	3
2	6.4	6.2	6
3	9.6	9.3	9
4	12.8	12.4	12
5	16.0	15.5	15
6	19.2	18.6	18
7	22.4	21.7	21
8	25.6	24.8	24
9	28.8	27.9	27

100 — Logarithms of Numbers — 150

150–200 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
150	17 609	638	667	696	725	754	782	811	840	869
151	17 898	926	955	984	*013	*041	*070	*099	*127	*156
152	18 184	213	241	270	298	327	355	384	412	441
153	469	498	526	554	583	611	639	667	696	724
154	18 752	780	808	837	865	893	921	949	977	*005
155	19 033	061	089	117	145	173	201	229	257	285
156	312	340	368	396	424	451	479	507	535	562
157	590	618	645	673	700	728	756	783	811	838
158	19 866	893	921	948	976	*003	*030	*058	*085	*112
159	20 140	167	194	222	249	276	303	330	358	385
160	20 412	439	466	493	520	548	575	602	629	656
161	683	710	737	763	790	817	844	871	898	925
162	20 952	978	*005	*032	*059	*085	*112	*139	*165	*192
163	21 219	245	272	299	325	352	378	405	431	458
164	484	511	537	564	590	617	643	669	696	722
165	21 748	775	801	827	854	880	906	932	958	985
166	22 011	037	063	089	115	141	167	194	220	246
167	272	298	324	350	376	401	427	453	479	505
168	531	557	583	608	634	660	686	712	737	763
169	22 789	814	840	866	891	917	943	968	994	*019
170	23 045	070	096	121	147	172	198	223	249	274
171	300	325	350	376	401	426	452	477	502	528
172	553	578	603	629	654	679	704	729	754	779
173	23 805	830	855	880	905	930	955	980	*005	*030
174	24 055	080	105	130	155	180	204	229	254	279
175	304	329	353	378	403	428	452	477	502	527
176	551	576	601	625	650	674	699	724	748	773
177	24 797	822	846	871	895	920	944	969	993	*018
178	25 042	066	091	115	139	164	188	212	237	261
179	285	310	334	358	382	406	431	455	479	503
180	25 527	551	575	600	624	648	672	696	720	744
181	25 768	792	816	840	864	888	912	935	959	983
182	26 007	031	055	079	102	126	150	174	198	221
183	245	269	293	316	340	364	387	411	435	458
184	482	505	529	553	576	600	623	647	670	694
185	717	741	764	788	811	834	858	881	905	928
186	26 951	975	998	*021	*045	*068	*091	*114	*138	*161
187	27 184	207	231	254	277	300	323	346	370	393
188	416	439	462	485	508	531	554	577	600	623
189	646	669	692	715	738	761	784	807	830	852
190	27 875	898	921	944	967	989	*012	*035	*058	*081
191	28 103	126	149	171	194	217	240	262	285	307
192	330	353	375	398	421	443	466	488	511	533
193	556	578	601	623	646	668	691	713	735	758
194	28 780	803	825	847	870	892	914	937	959	981
195	29 003	026	048	070	092	115	137	159	181	203
196	226	248	270	292	314	336	358	380	403	425
197	447	469	491	513	535	557	579	601	623	645
198	667	688	710	732	754	776	798	820	842	863
199	29 885	907	929	951	973	994	*016	*038	*060	*081
200	30 103	125	146	168	190	211	233	255	276	298
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	29	28	27
1	2.9	2.8	2.7
2	5.8	5.6	5.4
3	8.7	8.4	8.1
4	11.6	11.2	10.8
5	14.5	14.0	13.5
6	17.4	16.8	16.2
7	20.3	19.6	18.9
8	23.2	22.4	21.6
9	26.1	25.2	24.3

n \ d	26	25	24
1	2.6	2.5	2.4
2	5.2	5.0	4.8
3	7.8	7.5	7.2
4	10.4	10.0	9.6
5	13.0	12.5	12.0
6	15.6	15.0	14.4
7	18.2	17.5	16.8
8	20.8	20.0	19.2
9	23.4	22.5	21.6

n \ d	23	22	21
1	2.3	2.2	2.1
2	4.6	4.4	4.2
3	6.9	6.6	6.3
4	9.2	8.8	8.4
5	11.5	11.0	10.5
6	13.8	13.2	12.6
7	16.1	15.4	14.7
8	18.4	17.6	16.8
9	20.7	19.8	18.9

Prop. Parts

200–250 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
200	30 103	125	146	168	190	211	233	255	276	298
201	320	341	363	384	406	428	449	471	492	514
202	535	557	578	600	621	643	664	685	707	728
203	750	771	792	814	835	856	878	899	920	942
204	30 963	984	*006	*027	*048	*069	*091	*112	*133	*154
205	31 175	197	218	239	260	281	302	323	345	366
206	387	408	429	450	471	492	513	534	555	576
207	597	618	639	660	681	702	723	744	765	785
208	31 806	827	848	869	890	911	931	952	973	994
209	32 015	035	056	077	098	118	139	160	181	201
210	32 222	243	263	284	305	325	346	366	387	408
211	428	449	469	490	510	531	552	572	593	613
212	634	654	675	695	715	736	756	777	797	818
213	32 838	858	879	899	919	940	960	980	*001	*021
214	33 041	062	082	102	122	143	163	183	203	224
215	244	264	284	304	325	345	365	385	405	425
216	445	465	486	506	526	546	566	586	606	626
217	646	666	686	706	726	746	766	786	806	826
218	33 846	866	885	905	925	945	965	985	*005	*025
219	34 044	064	084	104	124	143	163	183	203	223
220	34 242	262	282	301	321	341	361	380	400	420
221	439	459	479	498	518	537	557	577	596	616
222	635	655	674	694	713	733	753	772	792	811
223	34 830	850	869	889	908	928	947	967	986	*005
224	35 025	044	064	083	102	122	141	160	180	199
225	218	238	257	276	295	315	334	353	372	392
226	411	430	449	468	488	507	526	545	564	583
227	603	622	641	660	679	698	717	736	755	774
228	793	813	832	851	870	889	908	927	946	965
229	35 984	*003	*021	*040	*059	*078	*097	*116	*135	*154
230	36 173	192	211	229	248	267	286	305	324	342
231	361	380	399	418	436	455	474	493	511	530
232	549	568	586	605	624	642	661	680	698	717
233	736	754	773	791	810	829	847	866	884	903
234	36 922	940	959	977	996	*014	*033	*051	*070	*088
235	37 107	125	144	162	181	199	218	236	254	273
236	291	310	328	346	365	383	401	420	438	457
237	475	493	511	530	548	566	585	603	621	639
238	658	676	694	712	731	749	767	785	803	822
239	37 840	858	876	894	912	931	949	967	985	*003
240	38 021	039	057	075	093	112	130	148	166	184
241	202	220	238	256	274	292	310	328	346	364
242	382	399	417	435	453	471	489	507	525	543
243	561	578	596	614	632	650	668	686	703	721
244	739	757	775	792	810	828	846	863	881	899
245	38 917	934	952	970	987	*005	*023	*041	*058	*076
246	39 094	111	129	146	164	182	199	217	235	252
247	270	287	305	322	340	358	375	393	410	428
248	445	463	480	498	515	533	550	568	585	602
249	620	637	655	672	690	707	724	742	759	777
250	39 794	811	829	846	863	881	898	915	933	950
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	22	21
1	2.2	2.1
2	4.4	4.2
3	6.6	6.3
4	8.8	8.4
5	11.0	10.5
6	13.2	12.6
7	15.4	14.7
8	17.6	16.8
9	19.8	18.9

n \ d	20	19
1	2	1.9
2	4	3.8
3	6	5.7
4	8	7.6
5	10	9.5
6	12	11.4
7	14	13.3
8	16	15.2
9	18	17.1

n \ d	18	17
1	1.8	1.7
2	3.6	3.4
3	5.4	5.1
4	7.2	6.8
5	9.0	8.5
6	10.8	10.2
7	12.6	11.9
8	14.4	13.6
9	16.2	15.3

Prop. Parts

Prop. Parts

n \ d	18	17
1	1.8	1.7
2	3.6	3.4
3	5.4	5.1
4	7.2	6.8
5	9.0	8.5
6	10.8	10.2
7	12.6	11.9
8	14.4	13.6
9	16.2	15.3

n \ d	16
1	1.6
2	3.2
3	4.8
4	6.4
5	8.0
6	9.6
7	11.2
8	12.8
9	14.4

n \ d	15	14
1	1.5	1.4
2	3.0	2.8
3	4.5	4.2
4	6.0	5.6
5	7.5	7.0
6	9.0	8.4
7	10.5	9.8
8	12.0	11.2
9	13.5	12.6

N	0	1	2	3	4	5	6	7	8	9
250	39 794	811	829	846	863	881	898	915	933	950
251	39 967	985	*002	*019	*037	*054	*071	*088	*106	*123
252	40 140	157	175	192	209	226	243	261	278	295
253	312	329	346	364	381	398	415	432	449	466
254	483	500	518	535	552	569	586	603	620	637
255	654	671	688	705	722	739	756	773	790	807
256	824	841	858	875	892	909	926	943	960	976
257	40 993	*010	*027	*044	*061	*078	*095	*111	*128	*145
258	41 162	179	196	212	229	246	263	280	296	313
259	330	347	363	380	397	414	430	447	464	481
260	41 497	514	531	547	564	581	597	614	631	647
261	664	681	697	714	731	747	764	780	797	814
262	830	847	863	880	896	913	929	946	963	979
263	41 996	*012	*029	*045	*062	*078	*095	*111	*127	*144
264	42 160	177	193	210	226	243	259	275	292	308
265	325	341	357	374	390	406	423	439	455	472
266	488	504	521	537	553	570	586	602	619	635
267	651	667	684	700	716	732	749	765	781	797
268	813	830	846	862	878	894	911	927	943	959
269	42 975	991	*008	*024	*040	*056	*072	*088	*104	*120
270	43 136	152	169	185	201	217	233	249	265	281
271	297	313	329	345	361	377	393	409	425	441
272	457	473	489	505	521	537	553	569	584	600
273	616	632	648	664	680	696	712	727	743	759
274	775	791	807	823	838	854	870	886	902	917
275	43 933	949	965	981	996	*012	*028	*044	*059	*075
276	44 091	107	122	138	154	170	185	201	217	232
277	248	264	279	295	311	326	342	358	373	389
278	404	420	436	451	467	483	498	514	529	545
279	560	576	592	607	623	638	654	669	685	700
280	44 716	731	747	762	778	793	809	824	840	855
281	44 871	886	902	917	932	948	963	979	994	*010
282	45 025	040	056	071	086	102	117	133	148	163
283	179	194	209	225	240	255	271	286	301	317
284	332	347	362	378	393	408	423	439	454	469
285	484	500	515	530	545	561	576	591	606	621
286	637	652	667	682	697	712	728	743	758	773
287	788	803	818	834	849	864	879	894	909	924
288	45 939	954	969	984	*000	*015	*030	*045	*060	*075
289	46 090	105	120	135	150	165	180	195	210	225
290	46 240	255	270	285	300	315	330	345	359	374
291	389	404	419	434	449	464	479	494	509	523
292	538	553	568	583	598	613	627	642	657	672
293	687	702	716	731	746	761	776	790	805	820
294	835	850	864	879	894	909	923	938	953	967
295	46 982	997	*012	*026	*041	*056	*070	*085	*100	*114
296	47 129	144	159	173	188	202	217	232	246	261
297	276	290	305	319	334	349	363	378	392	407
298	422	436	451	465	480	494	509	524	538	553
299	567	582	596	611	625	640	654	669	683	698
300	47 712	727	741	756	770	784	799	813	828	842
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

300–350 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
300	47 712	727	741	756	770	784	799	813	828	842
301	47 857	871	885	900	914	929	943	958	972	986
302	48 001	015	029	044	058	073	087	101	116	130
303	144	159	173	187	202	216	230	244	259	273
304	287	302	316	330	344	359	373	387	401	416
305	430	444	458	473	487	501	515	530	544	558
306	572	586	601	615	629	643	657	671	686	700
307	714	728	742	756	770	785	799	813	827	841
308	855	869	883	897	911	926	940	954	968	982
309	48 996	*010	*024	*038	*052	*066	*080	*094	*108	*122
310	49 136	150	164	178	192	206	220	234	248	262
311	276	290	304	318	332	346	360	374	388	402
312	415	429	443	457	471	485	499	513	527	541
313	554	568	582	596	610	624	638	651	665	679
314	693	707	721	734	748	762	776	790	803	817
315	831	845	859	872	886	900	914	927	941	955
316	49 969	982	996	*010	*024	*037	*051	*065	*079	*092
317	50 106	120	133	147	161	174	188	202	215	229
318	243	256	270	284	297	311	325	338	352	365
319	379	393	406	420	433	447	461	474	488	501
320	50 515	529	542	556	569	583	596	610	623	637
321	651	664	678	691	705	718	732	745	759	772
322	786	799	813	826	840	853	866	880	893	907
323	50 920	934	947	961	974	987	*001	*014	*028	*041
324	51 055	068	081	095	108	121	135	148	162	175
325	188	202	215	228	242	255	268	282	295	308
326	322	335	348	362	375	388	402	415	428	441
327	455	468	481	495	508	521	534	548	561	574
328	587	601	614	627	640	654	667	680	693	706
329	720	733	746	759	772	786	799	812	825	838
330	51 851	865	878	891	904	917	930	943	957	970
331	51 983	996	*009	*022	*035	*048	*061	*075	*088	*101
332	52 114	127	140	153	166	179	192	205	218	231
333	244	257	270	284	297	310	323	336	349	362
334	375	388	401	414	427	440	453	466	479	492
335	504	517	530	543	556	569	582	595	608	621
336	634	647	660	673	686	699	711	724	737	750
337	763	776	789	802	815	827	840	853	866	879
338	52 892	905	917	930	943	956	969	982	994	*007
339	53 020	033	046	058	071	084	097	110	122	135
340	53 148	161	173	186	199	212	224	237	250	263
341	275	288	301	314	326	339	352	364	377	390
342	403	415	428	441	453	466	479	491	504	517
343	529	542	555	567	580	593	605	618	631	643
344	656	668	681	694	706	719	732	744	757	769
345	782	794	807	820	832	845	857	870	882	895
346	53 908	920	933	945	958	970	983	995	*008	*020
347	54 033	045	058	070	083	095	108	120	133	145
348	158	170	183	195	208	220	233	245	258	270
349	283	295	307	320	332	345	357	370	382	394
350	54 407	419	432	444	456	469	481	494	506	518
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	15	14
1	1.5	1.4
2	3.0	2.8
3	4.5	4.2
4	6.0	5.6
5	7.5	7.0
6	9.0	8.4
7	10.5	9.8
8	12.0	11.2
9	13.5	12.6

n \ d	13	12
1	1.3	1.2
2	2.6	2.4
3	3.9	3.6
4	5.2	4.8
5	6.5	6.0
6	7.8	7.2
7	9.1	8.4
8	10.4	9.6
9	11.7	10.8

Prop. Parts

N	0	1	2	3	4	5	6	7	8	9
350	54 407	419	432	444	456	469	481	494	506	518
351	531	543	555	568	580	593	605	617	630	642
352	654	667	679	691	704	716	728	741	753	765
353	777	790	802	814	827	839	851	864	876	888
354	54 900	913	925	937	949	962	974	986	998	*011
355	55 023	035	047	060	072	084	096	108	121	133
356	145	157	169	182	194	206	218	230	242	255
357	267	279	291	303	315	328	340	352	364	376
358	388	400	413	425	437	449	461	473	485	497
359	509	522	534	546	558	570	582	594	606	618
360	55 630	642	654	666	678	691	703	715	727	739
361	751	763	775	787	799	811	823	835	847	859
362	871	883	895	907	919	931	943	955	967	979
363	55 991	*003	*015	*027	*038	*050	*062	*074	*086	*098
364	56 110	122	134	146	158	170	182	194	205	217
365	229	241	253	265	277	289	301	312	324	336
366	348	360	372	384	396	407	419	431	443	455
367	467	478	490	502	514	526	538	549	561	573
368	585	597	608	620	632	644	656	667	679	691
369	703	714	726	738	750	761	773	785	797	808
370	56 820	832	844	855	867	879	891	902	914	926
371	56 937	949	961	972	984	996	*008	*019	*031	*043
372	57 054	066	078	089	101	113	124	136	148	159
373	171	183	194	206	217	229	241	252	264	276
374	287	299	310	322	334	345	357	368	380	392
375	403	415	426	438	449	461	473	484	496	507
376	519	530	542	553	565	576	588	600	611	623
377	634	646	657	669	680	692	703	715	726	738
378	749	761	772	784	795	807	818	830	841	852
379	864	875	887	898	910	921	933	944	955	967
380	57 978	990	*001	*013	*024	*035	*047	*058	*070	*081
381	58 092	104	115	127	138	149	161	172	184	195
382	206	218	229	240	252	263	274	286	297	309
383	320	331	343	354	365	377	388	399	410	422
384	433	444	456	467	478	490	501	512	524	535
385	546	557	569	580	591	602	614	625	636	647
386	659	670	681	692	704	715	726	737	749	760
387	771	782	794	805	816	827	838	850	861	872
388	883	894	906	917	928	939	950	961	973	984
389	58 995	*006	*017	*028	*040	*051	*062	*073	*084	*095
390	59 106	118	129	140	151	162	173	184	195	207
391	218	229	240	251	262	273	284	295	306	318
392	329	340	351	362	373	384	395	406	417	428
393	439	450	461	472	483	494	506	517	528	539
394	550	561	572	583	594	605	616	627	638	649
395	660	671	682	693	704	715	726	737	748	759
396	770	780	791	802	813	824	835	846	857	868
397	879	890	901	912	923	934	945	956	966	977
398	59 988	999	*010	*021	*032	*043	*054	*065	*076	*086
399	60 097	108	119	130	141	152	163	173	184	195
400	60 206	217	228	239	249	260	271	282	293	304
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	13	12
1	1.3	1.2
2	2.6	2.4
3	3.9	3.6
4	5.2	4.8
5	6.5	6.0
6	7.8	7.2
7	9.1	8.4
8	10.4	9.6
9	11.7	10.8

n \ d	11	10
1	1.1	1
2	2.2	2
3	3.3	3
4	4.4	4
5	5.5	5
6	6.6	6
7	7.7	7
8	8.8	8
9	9.9	9

Prop. Parts

400–450 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
400	60 206	217	228	239	249	260	271	282	293	304
401	314	325	336	347	358	369	379	390	401	412
402	423	433	444	455	466	477	487	498	509	520
403	531	541	552	563	574	584	595	606	617	627
404	638	649	660	670	681	692	703	713	724	735
405	746	756	767	778	788	799	810	821	831	842
406	853	863	874	885	895	906	917	927	938	949
407	60 959	970	981	991	*002	*013	*023	*034	*045	*055
408	61 066	077	087	098	109	119	130	140	151	162
409	172	183	194	204	215	225	236	247	257	268
410	61 278	289	300	310	321	331	342	352	363	374
411	384	395	405	416	426	437	448	458	469	479
412	490	500	511	521	532	542	553	563	574	584
413	595	606	616	627	637	648	658	669	679	690
414	700	711	721	731	742	752	763	773	784	794
415	805	815	826	836	847	857	868	878	888	899
416	61 909	920	930	941	951	962	972	982	993	*003
417	62 014	024	034	045	055	066	076	086	097	107
418	118	128	138	149	159	170	180	190	201	211
419	221	232	242	252	263	273	284	294	304	315
420	62 325	335	346	356	366	377	387	397	408	418
421	428	439	449	459	469	480	490	500	511	521
422	531	542	552	562	572	583	593	603	613	624
423	634	644	655	665	675	685	696	706	716	726
424	737	747	757	767	778	788	798	808	818	829
425	839	849	859	870	880	890	900	910	921	931
426	62 941	951	961	972	982	992	*002	*012	*022	*033
427	63 043	053	063	073	083	094	104	114	124	134
428	144	155	165	175	185	195	205	215	225	236
429	246	256	266	276	286	296	306	317	327	337
430	63 347	357	367	377	387	397	407	417	428	438
431	448	458	468	478	488	498	508	518	528	538
432	548	558	568	579	589	599	609	619	629	639
433	649	659	669	679	689	699	709	719	729	739
434	749	759	769	779	789	799	809	819	829	839
435	849	859	869	879	889	899	909	919	929	939
436	63 949	959	969	979	988	998	*008	*018	*028	*038
437	64 048	058	068	078	088	098	108	118	128	137
438	147	157	167	177	187	197	207	217	227	237
439	246	256	266	276	286	296	306	316	326	335
440	64 345	355	365	375	385	395	404	414	424	434
441	444	454	464	473	483	493	503	513	523	532
442	542	552	562	572	582	591	601	611	621	631
443	640	650	660	670	680	689	699	709	719	729
444	738	748	758	768	777	787	797	807	816	826
445	836	846	856	865	875	885	895	904	914	924
446	64 933	943	953	963	972	982	992	*002	*011	*021
447	65 031	040	050	060	070	079	089	099	108	118
448	128	137	147	157	167	176	186	196	205	215
449	225	234	244	254	263	273	283	292	302	312
450	65 321	331	341	350	360	369	379	389	398	408
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	11	10	9
1	1.1	1	0.9
2	2.2	2	1.8
3	3.3	3	2.7
4	4.4	4	3.6
5	5.5	5	4.5
6	6.6	6	5.4
7	7.7	7	6.3
8	8.8	8	7.2
9	9.9	9	8.1

400 — Logarithms of Numbers — 450

450–500 **Five Places**

Prop. Parts

n \ d	10	9	8
1	1	0.9	0.8
2	2	1.8	1.6
3	3	2.7	2.4
4	4	3.6	3.2
5	5	4.5	4.0
6	6	5.4	4.8
7	7	6.3	5.6
8	8	7.2	6.4
9	9	8.1	7.2

N	0	1	2	3	4	5	6	7	8	9
450	65 321	331	341	350	360	369	379	389	398	408
451	418	427	437	447	456	466	475	485	495	504
452	514	523	533	543	552	562	571	581	591	600
453	610	619	629	639	648	658	667	677	686	696
454	706	715	725	734	744	753	763	772	782	792
455	801	811	820	830	839	849	858	868	877	887
456	896	906	916	925	935	944	954	963	973	982
457	65 992	*001	*011	*020	*030	*039	*049	*058	*068	*077
458	66 087	096	106	115	124	134	143	153	162	172
459	181	191	200	210	219	229	238	247	257	266
460	66 276	285	295	304	314	323	332	342	351	361
461	370	380	389	398	408	417	427	436	445	455
462	464	474	483	492	502	511	521	530	539	549
463	558	567	577	586	596	605	614	624	633	642
464	652	661	671	680	689	699	708	717	727	736
465	745	755	764	773	783	792	801	811	820	829
466	839	848	857	867	876	885	894	904	913	922
467	66 932	941	950	960	969	978	987	997	*006	*015
468	67 025	034	043	052	062	071	080	089	099	108
469	117	127	136	145	154	164	173	182	191	201
470	67 210	219	228	237	247	256	265	274	284	293
471	302	311	321	330	339	348	357	367	376	385
472	394	403	413	422	431	440	449	459	468	477
473	486	495	504	514	523	532	541	550	560	569
474	578	587	596	605	614	624	633	642	651	660
475	669	679	688	697	706	715	724	733	742	752
476	761	770	779	788	797	806	815	825	834	843
477	852	861	870	879	888	897	906	916	925	934
478	67 943	952	961	970	979	988	997	*006	*015	*024
479	68 034	043	052	061	070	079	088	097	106	115
480	68 124	133	142	151	160	169	178	187	196	205
481	215	224	233	242	251	260	269	278	287	296
482	305	314	323	332	341	350	359	368	377	386
483	395	404	413	422	431	440	449	458	467	476
484	485	494	502	511	520	529	538	547	556	565
485	574	583	592	601	610	619	628	637	646	655
486	664	673	681	690	699	708	717	726	735	744
487	753	762	771	780	789	797	806	815	824	833
488	842	851	860	869	878	886	895	904	913	922
489	68 931	940	949	958	966	975	984	993	*002	*011
490	69 020	028	037	046	055	064	073	082	090	099
491	108	117	126	135	144	152	161	170	179	188
492	197	205	214	223	232	241	249	258	267	276
493	285	294	302	311	320	329	338	346	355	364
494	373	381	390	399	408	417	425	434	443	452
495	461	469	478	487	496	504	513	522	531	539
496	548	557	566	574	583	592	601	609	618	627
497	636	644	653	662	671	679	688	697	705	714
498	723	732	740	749	758	767	775	784	793	801
499	810	819	827	836	845	854	862	871	880	888
500	69 897	906	914	923	932	940	949	958	966	975
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

450 — Logarithms of Numbers — 500

500–550 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
500	69 897	906	914	923	932	940	949	958	966	975
501	69 984	992	*001	*010	*018	*027	*036	*044	*053	*062
502	70 070	079	088	096	105	114	122	131	140	148
503	157	165	174	183	191	200	209	217	226	234
504	243	252	260	269	278	286	295	303	312	321
505	329	338	346	355	364	372	381	389	398	406
506	415	424	432	441	449	458	467	475	484	492
507	501	509	518	526	535	544	552	561	569	578
508	586	595	603	612	621	629	638	646	655	663
509	672	680	689	697	706	714	723	731	740	749
510	70 757	766	774	783	791	800	808	817	825	834
511	842	851	859	868	876	885	893	902	910	919
512	70 927	935	944	952	961	969	978	986	995	*003
513	71 012	020	029	037	046	054	063	071	079	088
514	096	105	113	122	130	139	147	155	164	172
515	181	189	198	206	214	223	231	240	248	257
516	265	273	282	290	299	307	315	324	332	341
517	349	357	366	374	383	391	399	408	416	425
518	433	441	450	458	466	475	483	492	500	508
519	517	525	533	542	550	559	567	575	584	592
520	71 600	609	617	625	634	642	650	659	667	675
521	684	692	700	709	717	725	734	742	750	759
522	767	775	784	792	800	809	817	825	834	842
523	850	858	867	875	883	892	900	908	917	925
524	71 933	941	950	958	966	975	983	991	999	*008
525	72 016	024	032	041	049	057	066	074	082	090
526	099	107	115	123	132	140	148	156	165	173
527	181	189	198	206	214	222	230	239	247	255
528	263	272	280	288	296	304	313	321	329	337
529	346	354	362	370	378	387	395	403	411	419
530	72 428	436	444	452	460	469	477	485	493	501
531	509	518	526	534	542	550	558	567	575	583
532	591	599	607	616	624	632	640	648	656	665
533	673	681	689	697	705	713	722	730	738	746
534	754	762	770	779	787	795	803	811	819	827
535	835	843	852	860	868	876	884	892	900	908
536	916	925	933	941	949	957	965	973	981	989
537	72 997	*006	*014	*022	*030	*038	*046	*054	*062	*070
538	73 078	086	094	102	111	119	127	135	143	151
539	159	167	175	183	191	199	207	215	223	231
540	73 239	247	255	263	272	280	288	296	304	312
541	320	328	336	344	352	360	368	376	384	392
542	400	408	416	424	432	440	448	456	464	472
543	480	488	496	504	512	520	528	536	544	552
544	560	568	576	584	592	600	608	616	624	632
545	640	648	656	664	672	679	687	695	703	711
546	719	727	735	743	751	759	767	775	783	791
547	799	807	815	823	830	838	846	854	862	870
548	878	886	894	902	910	918	926	933	941	949
549	73 957	965	973	981	989	997	*005	*013	*020	*028
550	74 036	044	052	060	068	076	084	092	099	107
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	9	8	7
1	0.9	0.8	0.7
2	1.8	1.6	1.4
3	2.7	2.4	2.1
4	3.6	3.2	2.8
5	4.5	4.0	3.5
6	5.4	4.8	4.2
7	6.3	5.6	4.9
8	7.2	6.4	5.6
9	8.1	7.2	6.3

Prop. Parts

550–600 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
550	74 036	044	052	060	068	076	084	092	099	107
551	115	123	131	139	147	155	162	170	178	186
552	194	202	210	218	225	233	241	249	257	265
553	273	280	288	296	304	312	320	327	335	343
554	351	359	367	374	382	390	398	406	414	421
555	429	437	445	453	461	468	476	484	492	500
556	507	515	523	531	539	547	554	562	570	578
557	586	593	601	609	617	624	632	640	648	656
558	663	671	679	687	695	702	710	718	726	733
559	741	749	757	764	772	780	788	796	803	811
560	74 819	827	834	842	850	858	865	873	881	889
561	896	904	912	920	927	935	943	950	958	966
562	74 974	981	989	997	*005	*012	*020	*028	*035	*043
563	75 051	059	066	074	082	089	097	105	113	120
564	128	136	143	151	159	166	174	182	189	197
565	205	213	220	228	236	243	251	259	266	274
566	282	289	297	305	312	320	328	335	343	351
567	358	366	374	381	389	397	404	412	420	427
568	435	442	450	458	465	473	481	488	496	504
569	511	519	526	534	542	549	557	565	572	580
570	75 587	595	603	610	618	626	633	641	648	656
571	664	671	679	686	694	702	709	717	724	732
572	740	747	755	762	770	778	785	793	800	808
573	815	823	831	838	846	853	861	868	876	884
574	891	899	906	914	921	929	937	944	952	959
575	75 967	974	982	989	997	*005	*012	*020	*027	*035
576	76 042	050	057	065	072	080	087	095	103	110
577	118	125	133	140	148	155	163	170	178	185
578	193	200	208	215	223	230	238	245	253	260
579	268	275	283	290	298	305	313	320	328	335
580	76 343	350	358	365	373	380	388	395	403	410
581	418	425	433	440	448	455	462	470	477	485
582	492	500	507	515	522	530	537	545	552	559
583	567	574	582	589	597	604	612	619	626	634
584	641	649	656	664	671	678	686	693	701	708
585	716	723	730	738	745	753	760	768	775	782
586	790	797	805	812	819	827	834	842	849	856
587	864	871	879	886	893	901	908	916	923	930
588	76 938	945	953	960	967	975	982	989	997	*004
589	77 012	019	026	034	041	048	056	063	070	078
590	77 085	093	100	107	115	122	129	137	144	151
591	159	166	173	181	188	195	203	210	217	225
592	232	240	247	254	262	269	276	283	291	298
593	305	313	320	327	335	342	349	357	364	371
594	379	386	393	401	408	415	422	430	437	444
595	452	459	466	474	481	488	495	503	510	517
596	525	532	539	546	554	561	568	576	583	590
597	597	605	612	619	627	634	641	648	656	663
598	670	677	685	692	699	706	714	721	728	735
599	743	750	757	764	772	779	786	793	801	808
600	77 815	822	830	837	844	851	859	866	873	880
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	8	7
1	0.8	0.7
2	1.6	1.4
3	2.4	2.1
4	3.2	2.8
5	4.0	3.5
6	4.8	4.2
7	5.6	4.9
8	6.4	5.6
9	7.2	6.3

600–650 Five Places

N	0	1	2	3	4	5	6	7	8	9
600	77 815	822	830	837	844	851	859	866	873	880
601	887	895	902	909	916	924	931	938	945	952
602	77 960	967	974	981	988	996	*003	*010	*017	*025
603	78 032	039	046	053	061	068	075	082	089	097
604	104	111	118	125	132	140	147	154	161	168
605	176	183	190	197	204	211	219	226	233	240
606	247	254	262	269	276	283	290	297	305	312
607	319	326	333	340	347	355	362	369	376	383
608	390	398	405	412	419	426	433	440	447	455
609	462	469	476	483	490	497	504	512	519	526
610	78 533	540	547	554	561	569	576	583	590	597
611	604	611	618	625	633	640	647	654	661	668
612	675	682	689	696	704	711	718	725	732	739
613	746	753	760	767	774	781	789	796	803	810
614	817	824	831	838	845	852	859	866	873	880
615	888	895	902	909	916	923	930	937	944	951
616	78 958	965	972	979	986	993	*000	*007	*014	*021
617	79 029	036	043	050	057	064	071	078	085	092
618	099	106	113	120	127	134	141	148	155	162
619	169	176	183	190	197	204	211	218	225	232
620	79 239	246	253	260	267	274	281	288	295	302
621	309	316	323	330	337	344	351	358	365	372
622	379	386	393	400	407	414	421	428	435	442
623	449	456	463	470	477	484	491	498	505	511
624	518	525	532	539	546	553	560	567	574	581
625	588	595	602	609	616	623	630	637	644	650
626	657	664	671	678	685	692	699	706	713	720
627	727	734	741	748	754	761	768	775	782	789
628	796	803	810	817	824	831	837	844	851	858
629	865	872	879	886	893	900	906	913	920	927
630	79 934	941	948	955	962	969	975	982	989	996
631	80 003	010	017	024	030	037	044	051	058	065
632	072	079	085	092	099	106	113	120	127	134
633	140	147	154	161	168	175	182	188	195	202
634	209	216	223	229	236	243	250	257	264	271
635	277	284	291	298	305	312	318	325	332	339
636	346	353	359	366	373	380	387	393	400	407
637	414	421	428	434	441	448	455	462	468	475
638	482	489	496	502	509	516	523	530	536	543
639	550	557	564	570	577	584	591	598	604	611
640	80 618	625	632	638	645	652	659	665	672	679
641	686	693	699	706	713	720	726	733	740	747
642	754	760	767	774	781	787	794	801	808	814
643	821	828	835	841	848	855	862	868	875	882
644	889	895	902	909	916	922	929	936	943	949
645	80 956	963	969	976	983	990	996	*003	*010	*017
646	81 023	030	037	043	050	057	064	070	077	084
647	090	097	104	111	117	124	131	137	144	151
648	158	164	171	178	184	191	198	204	211	218
649	224	231	238	245	251	258	265	271	278	285
650	81 291	298	305	311	318	325	331	338	345	351
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	8	7	6
1	0.8	0.7	0.6
2	1.6	1.4	1.2
3	2.4	2.1	1.8
4	3.2	2.8	2.4
5	4.0	3.5	3.0
6	4.8	4.2	3.6
7	5.6	4.9	4.2
8	6.4	5.6	4.8
9	7.2	6.3	5.4

N	0	1	2	3	4	5	6	7	8	9
650	81 291	298	305	311	318	325	331	338	345	351
651	358	365	371	378	385	391	398	405	411	418
652	425	431	438	445	451	458	465	471	478	485
653	491	498	505	511	518	525	531	538	544	551
654	558	564	571	578	584	591	598	604	611	617
655	624	631	637	644	651	657	664	671	677	684
656	690	697	704	710	717	723	730	737	743	750
657	757	763	770	776	783	790	796	803	809	816
658	823	829	836	842	849	856	862	869	875	882
659	889	895	902	908	915	921	928	935	941	948
660	81 954	961	968	974	981	987	994	*000	*007	*014
661	82 020	027	033	040	046	053	060	066	073	079
662	086	092	099	105	112	119	125	132	138	145
663	151	158	164	171	178	184	191	197	204	210
664	217	223	230	236	243	249	256	263	269	276
665	282	289	295	302	308	315	321	328	334	341
666	347	354	360	367	373	380	387	393	400	406
667	413	419	426	432	439	445	452	458	465	471
668	478	484	491	497	504	510	517	523	530	536
669	543	549	556	562	569	575	582	588	595	601
670	82 607	614	620	627	633	640	646	653	659	666
671	672	679	685	692	698	705	711	718	724	730
672	737	743	750	756	763	769	776	782	789	795
673	802	808	814	821	827	834	840	847	853	860
674	866	872	879	885	892	898	905	911	918	924
675	930	937	943	950	956	963	969	975	982	988
676	82 995	*001	*008	*014	*020	*027	*033	*040	*046	*052
677	83 059	065	072	078	085	091	097	104	110	117
678	123	129	136	142	149	155	161	168	174	181
679	187	193	200	206	213	219	225	232	238	245
680	83 251	257	264	270	276	283	289	296	302	308
681	315	321	327	334	340	347	353	359	366	372
682	378	385	391	398	404	410	417	423	429	436
683	442	448	455	461	467	474	480	487	493	499
684	506	512	518	525	531	537	544	550	556	563
685	569	575	582	588	594	601	607	613	620	626
686	632	639	645	651	658	664	670	677	683	689
687	696	702	708	715	721	727	734	740	746	753
688	759	765	771	778	784	790	797	803	809	816
689	822	828	835	841	847	853	860	866	872	879
690	83 885	891	897	904	910	916	923	929	935	942
691	83 948	954	960	967	973	979	985	992	998	*004
692	84 011	017	023	029	036	042	048	055	061	067
693	073	080	086	092	098	105	111	117	123	130
694	136	142	148	155	161	167	173	180	186	192
695	198	205	211	217	223	230	236	242	248	255
696	261	267	273	280	286	292	298	305	311	317
697	323	330	336	342	348	354	361	367	373	379
698	386	392	398	404	410	417	423	429	435	442
699	448	454	460	466	473	479	485	491	497	504
700	84 510	516	522	528	535	541	547	553	559	566
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	7	6
1	0.7	0.6
2	1.4	1.2
3	2.1	1.8
4	2.8	2.4
5	3.5	3.0
6	4.2	3.6
7	4.9	4.2
8	5.6	4.8
9	6.3	5.4

700–750 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
700	84 510	516	522	528	535	541	547	553	559	566
701	572	578	584	590	597	603	609	615	621	628
702	634	640	646	652	658	665	671	677	683	689
703	696	702	708	714	720	726	733	739	745	751
704	757	763	770	776	782	788	794	800	807	813
705	819	825	831	837	844	850	856	862	868	874
706	880	887	893	899	905	911	917	924	930	936
707	84 942	948	954	960	967	973	979	985	991	997
708	85 003	009	016	022	028	034	040	046	052	058
709	065	071	077	083	089	095	101	107	114	120
710	85 126	132	138	144	150	156	163	169	175	181
711	187	193	199	205	211	217	224	230	236	242
712	248	254	260	266	272	278	285	291	297	303
713	309	315	321	327	333	339	345	352	358	364
714	370	376	382	388	394	400	406	412	418	425
715	431	437	443	449	455	461	467	473	479	485
716	491	497	503	509	516	522	528	534	540	546
717	552	558	564	570	576	582	588	594	600	606
718	612	618	625	631	637	643	649	655	661	667
719	673	679	685	691	697	703	709	715	721	727
720	85 733	739	745	751	757	763	769	775	781	788
721	794	800	806	812	818	824	830	836	842	848
722	854	860	866	872	878	884	890	896	902	908
723	914	920	926	932	938	944	950	956	962	968
724	85 974	980	986	992	998	*004	*010	*016	*022	*028
725	86 034	040	046	052	058	064	070	076	082	088
726	094	100	106	112	118	124	130	136	141	147
727	153	159	165	171	177	183	189	195	201	207
728	213	219	225	231	237	243	249	255	261	267
729	273	279	285	291	297	303	308	314	320	326
730	86 332	338	344	350	356	362	368	374	380	386
731	392	398	404	410	415	421	427	433	439	445
732	451	457	463	469	475	481	487	493	499	504
733	510	516	522	528	534	540	546	552	558	564
734	570	576	581	587	593	599	605	611	617	623
735	629	635	641	646	652	658	664	670	676	682
736	688	694	700	705	711	717	723	729	735	741
737	747	753	759	764	770	776	782	788	794	800
738	806	812	817	823	829	835	841	847	853	859
739	864	870	876	882	888	894	900	906	911	917
740	86 923	929	935	941	947	953	958	964	970	976
741	86 982	988	994	999	*005	*011	*017	*023	*029	*035
742	87 040	046	052	058	064	070	075	081	087	093
743	099	105	111	116	122	128	134	140	146	151
744	157	163	169	175	181	186	192	198	204	210
745	216	221	227	233	239	245	251	256	262	268
746	274	280	286	291	297	303	309	315	320	326
747	332	338	344	349	355	361	367	373	379	384
748	390	396	402	408	413	419	425	431	437	442
749	448	454	460	466	471	477	483	489	495	500
750	87 506	512	518	523	529	535	541	547	552	558
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	7	6	5
1	0.7	0.6	0.5
2	1.4	1.2	1.0
3	2.1	1.8	1.5
4	2.8	2.4	2.0
5	3.5	3.0	2.5
6	4.2	3.6	3.0
7	4.9	4.2	3.5
8	5.6	4.8	4.0
9	6.3	5.4	4.5

750–800 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
750	87 506	512	518	523	529	535	541	547	552	558
751	564	570	576	581	587	593	599	604	610	616
752	622	628	633	639	645	651	656	662	668	674
753	679	685	691	697	703	708	714	720	726	731
754	737	743	749	754	760	766	772	777	783	789
755	795	800	806	812	818	823	829	835	841	846
756	852	858	864	869	875	881	887	892	898	904
757	910	915	921	927	933	938	944	950	955	961
758	87 967	973	978	984	990	996	*001	*007	*013	*018
759	88 024	030	036	041	047	053	058	064	070	076
760	88 081	087	093	098	104	110	116	121	127	133
761	138	144	150	156	161	167	173	178	184	190
762	195	201	207	213	218	224	230	235	241	247
763	252	258	264	270	275	281	287	292	298	304
764	309	315	321	326	332	338	343	349	355	360
765	366	372	377	383	389	395	400	406	412	417
766	423	429	434	440	446	451	457	463	468	474
767	480	485	491	497	502	508	513	519	525	530
768	536	542	547	553	559	564	570	576	581	587
769	593	598	604	610	615	621	627	632	638	643
770	88 649	655	660	666	672	677	683	689	694	700
771	705	711	717	722	728	734	739	745	750	756
772	762	767	773	779	784	790	795	801	807	812
773	818	824	829	835	840	846	852	857	863	868
774	874	880	885	891	897	902	908	913	919	925
775	930	936	941	947	953	958	964	969	975	981
776	88 986	992	997	*003	*009	*014	*020	*025	*031	*037
777	89 042	048	053	059	064	070	076	081	087	092
778	098	104	109	115	120	126	131	137	143	148
779	154	159	165	170	176	182	187	193	198	204
780	89 209	215	221	226	232	237	243	248	254	260
781	265	271	276	282	287	293	298	304	310	315
782	321	326	332	337	343	348	354	360	365	371
783	376	382	387	393	398	404	409	415	421	426
784	432	437	443	448	454	459	465	470	476	481
785	487	492	498	504	509	515	520	526	531	537
786	542	548	553	559	564	570	575	581	586	592
787	597	603	609	614	620	625	631	636	642	647
788	653	658	664	669	675	680	686	691	697	702
789	708	713	719	724	730	735	741	746	752	757
790	89 763	768	774	779	785	790	796	801	807	812
791	818	823	829	834	840	845	851	856	862	867
792	873	878	883	889	894	900	905	911	916	922
793	927	933	938	944	949	955	960	966	971	977
794	89 982	988	993	998	*004	*009	*015	*020	*026	*031
795	90 037	042	048	053	059	064	069	075	080	086
796	091	097	102	108	113	119	124	129	135	140
797	146	151	157	162	168	173	179	184	189	195
798	200	206	211	217	222	227	233	238	244	249
799	255	260	266	271	276	282	287	293	298	304
800	90 309	314	320	325	331	336	342	347	352	358
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	6	5
1	0.6	0.5
2	1.2	1.0
3	1.8	1.5
4	2.4	2.0
5	3.0	2.5
6	3.6	3.0
7	4.2	3.5
8	4.8	4.0
9	5.4	4.5

800–850 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
800	90 309	314	320	325	331	336	342	347	352	358
801	363	369	374	380	385	390	396	401	407	412
802	417	423	428	434	439	445	450	455	461	466
803	472	477	482	488	493	499	504	509	515	520
804	526	531	536	542	547	553	558	563	569	574
805	580	585	590	596	601	607	612	617	623	628
806	634	639	644	650	655	660	666	671	677	682
807	687	693	698	703	709	714	720	725	730	736
808	741	747	752	757	763	768	773	779	784	789
809	795	800	806	811	816	822	827	832	838	843
810	90 849	854	859	865	870	875	881	886	891	897
811	902	907	913	918	924	929	934	940	945	950
812	90 956	961	966	972	977	982	988	993	998	*004
813	91 009	014	020	025	030	036	041	046	052	057
814	062	068	073	078	084	089	094	100	105	110
815	116	121	126	132	137	142	148	153	158	164
816	169	174	180	185	190	196	201	206	212	217
817	222	228	233	238	243	249	254	259	265	270
818	275	281	286	291	297	302	307	312	318	323
819	328	334	339	344	350	355	360	365	371	376
820	91 381	387	392	397	403	408	413	418	424	429
821	434	440	445	450	455	461	466	471	477	482
822	487	492	498	503	508	514	519	524	529	535
823	540	545	551	556	561	566	572	577	582	587
824	593	598	603	609	614	619	624	630	635	640
825	645	651	656	661	666	672	677	682	687	693
826	698	703	709	714	719	724	730	735	740	745
827	751	756	761	766	772	777	782	787	793	798
828	803	808	814	819	824	829	834	840	845	850
829	855	861	866	871	876	882	887	892	897	903
830	91 908	913	918	924	929	934	939	944	950	955
831	91 960	965	971	976	981	986	991	997	*002	*007
832	92 012	018	023	028	033	038	044	049	054	059
833	065	070	075	080	085	091	096	101	106	111
834	117	122	127	132	137	143	148	153	158	163
835	169	174	179	184	189	195	200	205	210	215
836	221	226	231	236	241	247	252	257	262	267
837	273	278	283	288	293	298	304	309	314	319
838	324	330	335	340	345	350	355	361	366	371
839	376	381	387	392	397	402	407	412	418	423
840	92 428	433	438	443	449	454	459	464	469	474
841	480	485	490	495	500	505	511	516	521	526
842	531	536	542	547	552	557	562	567	572	578
843	583	588	593	598	603	609	614	619	624	629
844	634	639	645	650	655	660	665	670	675	681
845	686	691	696	701	706	711	716	722	727	732
846	737	742	747	752	758	763	768	773	778	783
847	788	793	799	804	809	814	819	824	829	834
848	840	845	850	855	860	865	870	875	881	886
849	891	896	901	906	911	916	921	927	932	937
850	92 942	947	952	957	962	967	973	978	983	988
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	6	5
1	0.6	0.5
2	1.2	1.0
3	1.8	1.5
4	2.4	2.0
5	3.0	2.5
6	3.6	3.0
7	4.2	3.5
8	4.8	4.0
9	5.4	4.5

Prop. Parts

800 — Logarithms of Numbers — 850

850–900 **Five Places**

Prop. Parts

n \ d	6	5	4
1	0.6	0.5	0.4
2	1.2	1.0	0.8
3	1.8	1.5	1.2
4	2.4	2.0	1.6
5	3.0	2.5	2.0
6	3.6	3.0	2.4
7	4.2	3.5	2.8
8	4.8	4.0	3.2
9	5.4	4.5	3.6

N	0	1	2	3	4	5	6	7	8	9
850	92 942	947	952	957	962	967	973	978	983	988
851	92 993	998	*003	*008	*013	*018	*024	*029	*034	*039
852	93 044	049	054	059	064	069	075	080	085	090
853	095	100	105	110	115	120	125	131	136	141
854	146	151	156	161	166	171	176	181	186	192
855	197	202	207	212	217	222	227	232	237	242
856	247	252	258	263	268	273	278	283	288	293
857	298	303	308	313	318	323	328	334	339	344
858	349	354	359	364	369	374	379	384	389	394
859	399	404	409	414	420	425	430	435	440	445
860	93 450	455	460	465	470	475	480	485	490	495
861	500	505	510	515	520	526	531	536	541	546
862	551	556	561	566	571	576	581	586	591	596
863	601	606	611	616	621	626	631	636	641	646
864	651	656	661	666	671	676	682	687	692	697
865	702	707	712	717	722	727	732	737	742	747
866	752	757	762	767	772	777	782	787	792	797
867	802	807	812	817	822	827	832	837	842	847
868	852	857	862	867	872	877	882	887	892	897
869	902	907	912	917	922	927	932	937	942	947
870	93 952	957	962	967	972	977	982	987	992	997
871	94 002	007	012	017	022	027	032	037	042	047
872	052	057	062	067	072	077	082	086	091	096
873	101	106	111	116	121	126	131	136	141	146
874	151	156	161	166	171	176	181	186	191	196
875	201	206	211	216	221	226	231	236	240	245
876	250	255	260	265	270	275	280	285	290	295
877	300	305	310	315	320	325	330	335	340	345
878	349	354	359	364	369	374	379	384	389	394
879	399	404	409	414	419	424	429	433	438	443
880	94 448	453	458	463	468	473	478	483	488	493
881	498	503	507	512	517	522	527	532	537	542
882	547	552	557	562	567	571	576	581	586	591
883	596	601	606	611	616	621	626	630	635	640
884	645	650	655	660	665	670	675	680	685	689
885	694	699	704	709	714	719	724	729	734	738
886	743	748	753	758	763	768	773	778	783	787
887	792	797	802	807	812	817	822	827	832	836
888	841	846	851	856	861	866	871	876	880	885
889	890	895	900	905	910	915	919	924	929	934
890	94 939	944	949	954	959	963	968	973	978	983
891	94 988	993	998	*002	*007	*012	*017	*022	*027	*032
892	95 036	041	046	051	056	061	066	071	075	080
893	085	090	095	100	105	109	114	119	124	129
894	134	139	143	148	153	158	163	168	173	177
895	182	187	192	197	202	207	211	216	221	226
896	231	236	240	245	250	255	260	265	270	274
897	279	284	289	294	299	303	308	313	318	323
898	328	332	337	342	347	352	357	361	366	371
899	376	381	386	390	395	400	405	410	415	419
900	95 424	429	434	439	444	448	453	458	463	468
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

900–950 **Five Places**

N	0	1	2	3	4	5	6	7	8	9
900	95 424	429	434	439	444	448	453	458	463	468
901	472	477	482	487	492	497	501	506	511	516
902	521	525	530	535	540	545	550	554	559	564
903	569	574	578	583	588	593	598	602	607	612
904	617	622	626	631	636	641	646	650	655	660
905	665	670	674	679	684	689	694	698	703	708
906	713	718	722	727	732	737	742	746	751	756
907	761	766	770	775	780	785	789	794	799	804
908	809	813	818	823	828	832	837	842	847	852
909	856	861	866	871	875	880	885	890	895	899
910	95 904	909	914	918	923	928	933	938	942	947
911	952	957	961	966	971	976	980	985	990	995
912	95 999	*004	*009	*014	*019	*023	*028	*033	*038	*042
913	96 047	052	057	061	066	071	076	080	085	090
914	095	099	104	109	114	118	123	128	133	137
915	142	147	152	156	161	166	171	175	180	185
916	190	194	199	204	209	213	218	223	227	232
917	237	242	246	251	256	261	265	270	275	280
918	284	289	294	298	303	308	313	317	322	327
919	332	336	341	346	350	355	360	365	369	374
920	96 379	384	388	393	398	402	407	412	417	421
921	426	431	435	440	445	450	454	459	464	468
922	473	478	483	487	492	497	501	506	511	515
923	520	525	530	534	539	544	548	553	558	562
924	567	572	577	581	586	591	595	600	605	609
925	614	619	624	628	633	638	642	647	652	656
926	661	666	670	675	680	685	689	694	699	703
927	708	713	717	722	727	731	736	741	745	750
928	755	759	764	769	774	778	783	788	792	797
929	802	806	811	816	820	825	830	834	839	844
930	96 848	853	858	862	867	872	876	881	886	890
931	895	900	904	909	914	918	923	928	932	937
932	942	946	951	956	960	965	970	974	979	984
933	96 988	993	997	*002	*007	*011	*016	*021	*025	*030
934	97 035	039	044	049	053	058	063	067	072	077
935	081	086	090	095	100	104	109	114	118	123
936	128	132	137	142	146	151	155	160	165	169
937	174	179	183	188	192	197	202	206	211	216
938	220	225	230	234	239	243	248	253	257	262
939	267	271	276	280	285	290	294	299	304	308
940	97 313	317	322	327	331	336	340	345	350	354
941	359	364	368	373	377	382	387	391	396	400
942	405	410	414	419	424	428	433	437	442	447
943	451	456	460	465	470	474	479	483	488	493
944	497	502	506	511	516	520	525	529	534	539
945	543	548	552	557	562	566	571	575	580	585
946	589	594	598	603	607	612	617	621	626	630
947	635	640	644	649	653	658	663	667	672	676
948	681	685	690	695	699	704	708	713	717	722
949	727	731	736	740	745	749	754	759	763	768
950	97 772	777	782	786	791	795	800	804	809	813
N	0	1	2	3	4	5	6	7	8	9

Prop. Parts

n \ d	5	4
1	0.5	0.4
2	1.0	0.8
3	1.5	1.2
4	2.0	1.6
5	2.5	2.0
6	3.0	2.4
7	3.5	2.8
8	4.0	3.2
9	4.5	3.6

Prop. Parts

Prop. Parts

n \ d	5	4
1	0.5	0.4
2	1.0	0.8
3	1.5	1.2
4	2.0	1.6
5	2.5	2.0
6	3.0	2.4
7	3.5	2.8
8	4.0	3.2
9	4.5	3.6

N	0	1	2	3	4	5	6	7	8	9
950	97 772	777	782	786	791	795	800	804	809	813
951	818	823	827	832	836	841	845	850	855	859
952	864	868	873	877	882	886	891	896	900	905
953	909	914	918	923	928	932	937	941	946	950
954	97 955	959	964	968	973	978	982	987	991	996
955	98 000	005	009	014	019	023	028	032	037	041
956	046	050	055	059	064	068	073	078	082	087
957	091	096	100	105	109	114	118	123	127	132
958	137	141	146	150	155	159	164	168	173	177
959	182	186	191	195	200	204	209	214	218	223
960	98 227	232	236	241	245	250	254	259	263	268
961	272	277	281	286	290	295	299	304	308	313
962	318	322	327	331	336	340	345	349	354	358
963	363	367	372	376	381	385	390	394	399	403
964	408	412	417	421	426	430	435	439	444	448
965	453	457	462	466	471	475	480	484	489	493
966	498	502	507	511	516	520	525	529	534	538
967	543	547	552	556	561	565	570	574	579	583
968	588	592	597	601	605	610	614	619	623	628
969	632	637	641	646	650	655	659	664	668	673
970	98 677	682	686	691	695	700	704	709	713	717
971	722	726	731	735	740	744	749	753	758	762
972	767	771	776	780	784	789	793	798	802	807
973	811	816	820	825	829	834	838	843	847	851
974	856	860	865	869	874	878	883	887	892	896
975	900	905	909	914	918	923	927	932	936	941
976	945	949	954	958	963	967	972	976	981	985
977	98 989	994	998	*003	*007	*012	*016	*021	*025	*029
978	99 034	038	043	047	052	056	061	065	069	074
979	078	083	087	092	096	100	105	109	114	118
980	99 123	127	131	136	140	145	149	154	158	162
981	167	171	176	180	185	189	193	198	202	207
982	211	216	220	224	229	233	238	242	247	251
983	255	260	264	269	273	277	282	286	291	295
984	300	304	308	313	317	322	326	330	335	339
985	344	348	352	357	361	366	370	374	379	383
986	388	392	396	401	405	410	414	419	423	427
987	432	436	441	445	449	454	458	463	467	471
988	476	480	484	489	493	498	502	506	511	515
989	520	524	528	533	537	542	546	550	555	559
990	99 564	568	572	577	581	585	590	594	599	603
991	607	612	616	621	625	629	634	638	642	647
992	651	656	660	664	669	673	677	682	686	691
993	695	699	704	708	712	717	721	726	730	734
994	739	743	747	752	756	760	765	769	774	778
995	782	787	791	795	800	804	808	813	817	822
996	826	830	835	839	843	848	852	856	861	865
997	870	874	878	883	887	891	896	900	904	909
998	913	917	922	926	930	935	939	944	948	952
999	99 957	961	965	970	974	978	983	987	991	996
1000	00 000	004	009	013	017	022	026	030	035	039
N	0	1	2	3	4	5	6	7	8	9

FUNCTIONS OF NUMBERS

.01 to .49

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
.01	.0001	.000001	0.1000	0.2154	$\bar{2}.00000$	100000.000	.03142	.000079
.02	.0004	.000008	0.1414	0.2714	$\bar{2}.30103$	50000.000	.06283	.000314
.03	.0009	.000027	0.1732	0.3107	$\bar{2}.47712$	33333.333	.09425	.000707
.04	.0016	.000064	0.2000	0.3420	$\bar{2}.60206$	25000.000	.12566	.001257
.05	.0025	.000125	0.2236	0.3684	$\bar{2}.69897$	20000.000	.15708	.001964
.06	.0036	.000216	0.2449	0.3915	$\bar{2}.77815$	16666.667	.18850	.002827
.07	.0049	.000343	0.2646	0.4121	$\bar{2}.84510$	14285.714	.21991	.003849
.08	.0064	.000512	0.2828	0.4309	$\bar{2}.90309$	12500.000	.25133	.005027
.09	.0081	.000729	0.3000	0.4481	$\bar{2}.95424$	11111.111	.28274	.006362
.10	.0100	.001000	0.3162	0.4642	$\bar{1}.00000$	10000.000	.31416	.007854
.11	.0121	.001331	0.3317	0.4791	$\bar{1}.04139$	9090.909	.34558	.009503
.12	.0144	.001728	0.3464	0.4932	$\bar{1}.07918$	8333.333	.37699	.011310
.13	.0169	.002197	0.3606	0.5066	$\bar{1}.11394$	7692.308	.40841	.013273
.14	.0196	.002744	0.3742	0.5192	$\bar{1}.14613$	7142.857	.43982	.015394
.15	.0225	.003375	0.3873	0.5313	$\bar{1}.17609$	6666.667	.47124	.017672
.16	.0256	.004096	0.4000	0.5429	$\bar{1}.20412$	6250.000	.50265	.020106
.17	.0289	.004913	0.4123	0.5540	$\bar{1}.23045$	5882.353	.53407	.022698
.18	.0324	.005832	0.4243	0.5646	$\bar{1}.25527$	5555.556	.56549	.025447
.19	.0361	.006859	0.4359	0.5749	$\bar{1}.27875$	5263.158	.59690	.028353
.20	.0400	.008000	0.4472	0.5848	$\bar{1}.30103$	5000.000	.62832	.031416
.21	.0441	.009261	0.4583	0.5944	$\bar{1}.32222$	4761.905	.65973	.034636
.22	.0484	.010648	0.4690	0.6037	$\bar{1}.34242$	4545.455	.69115	.038013
.23	.0529	.012167	0.4796	0.6127	$\bar{1}.36173$	4347.826	.72257	.041548
.24	.0576	.013824	0.4899	0.6214	$\bar{1}.38021$	4166.667	.75398	.045239
.25	.0625	.015625	0.5000	0.6300	$\bar{1}.39794$	4000.000	.78540	.049087
.26	.0676	.017576	0.5099	0.6383	$\bar{1}.41497$	3846.154	.81681	.053093
.27	.0729	.019683	0.5196	0.6463	$\bar{1}.43136$	3703.704	.84823	.057256
.28	.0784	.021952	0.5292	0.6542	$\bar{1}.44716$	3571.429	.87965	.061575
.29	.0841	.024389	0.5385	0.6619	$\bar{1}.46240$	3448.276	.91106	.066052
.30	.0900	.027000	0.5477	0.6694	$\bar{1}.47712$	3333.333	.94248	.070686
.31	.0961	.029791	0.5568	0.6768	$\bar{1}.49136$	3225.807	.97389	.075477
.32	.1024	.032768	0.5657	0.6840	$\bar{1}.50515$	3125.000	1.00531	.080425
.33	.1089	.035937	0.5745	0.6910	$\bar{1}.51851$	3030.303	1.03673	.085530
.34	.1156	.039304	0.5831	0.6980	$\bar{1}.53148$	2941.177	1.06814	.090792
.35	.1225	.042875	0.5916	0.7047	$\bar{1}.54407$	2857.143	1.09956	.096211
.36	.1296	.046656	0.6000	0.7114	$\bar{1}.55630$	2777.778	1.13097	.101788
.37	.1369	.050653	0.6083	0.7179	$\bar{1}.56820$	2702.703	1.16239	.107521
.38	.1444	.054872	0.6164	0.7243	$\bar{1}.57978$	2631.579	1.19381	.113411
.39	.1521	.059319	0.6245	0.7306	$\bar{1}.59106$	2564.103	1.22522	.119459
.40	.1600	.064000	0.6325	0.7368	$\bar{1}.60206$	2500.000	1.2566	.125664
.41	.1681	.068921	0.6403	0.7429	$\bar{1}.61278$	2439.024	1.2881	.132025
.42	.1764	.074088	0.6481	0.7489	$\bar{1}.62325$	2380.952	1.3195	.138544
.43	.1849	.079507	0.6557	0.7548	$\bar{1}.63347$	2325.581	1.3509	.145220
.44	.1936	.085184	0.6633	0.7606	$\bar{1}.64345$	2272.727	1.3823	.152053
.45	.2025	.091125	0.6708	0.7663	$\bar{1}.65321$	2222.222	1.4137	.159043
.46	.2116	.097336	0.6782	0.7719	$\bar{1}.66276$	2173.913	1.4451	.166190
.47	.2209	.103823	0.6856	0.7775	$\bar{1}.67210$	2127.660	1.4765	.173494
.48	.2304	.110592	0.6928	0.7830	$\bar{1}.68124$	2083.333	1.5080	.180956
.49	.2401	.117649	0.7000	0.7884	$\bar{1}.69020$	2040.816	1.5394	.188574

FUNCTIONS OF NUMBERS (Continued)

.50 to .99

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
.50	.2500	.125000	0.7071	0.7937	$\bar{1}$.69897	2000.000	1.5708	.19635
.51	.2601	.132651	0.7141	0.7990	$\bar{1}$.70757	1960.784	1.6022	.20428
.52	.2704	.140608	0.7211	0.8041	$\bar{1}$.71600	1923.077	1.6336	.21237
.53	.2809	.148877	0.7280	0.8093	$\bar{1}$.72428	1886.793	1.6650	.22062
.54	.2916	.157464	0.7348	0.8143	$\bar{1}$.73239	1851.852	1.6965	.22902
.55	.3025	.166375	0.7416	0.8193	$\bar{1}$.74036	1818.182	1.7279	.23758
.56	.3136	.175616	0.7483	0.8243	$\bar{1}$.74819	1785.714	1.7593	.24630
.57	.3249	.185193	0.7550	0.8291	$\bar{1}$.75587	1754.386	1.7907	.25518
.58	.3364	.195112	0.7616	0.8340	$\bar{1}$.76343	1724.138	1.8221	.26401
.59	.3481	.205379	0.7681	0.8387	$\bar{1}$.77085	1694.915	1.8535	.27340
.60	.3600	.216000	0.7746	0.8434	$\bar{1}$.77815	1666.667	1.8850	.28274
.61	.3721	.226981	0.7810	0.8481	$\bar{1}$.78533	1639.344	1.9164	.29225
.62	.3844	.238328	0.7874	0.8527	$\bar{1}$.79239	1612.903	1.9478	.30191
.63	.3969	.250047	0.7937	0.8573	$\bar{1}$.79934	1587.302	1.9792	.31173
.64	.4096	.262144	0.8000	0.8618	$\bar{1}$.80618	1562.500	2.0106	.32170
.65	.4225	.274625	0.8062	0.8662	$\bar{1}$.81291	1538.462	2.0420	.33183
.66	.4356	.287496	0.8124	0.8707	$\bar{1}$.81954	1515.152	2.0735	.34212
.67	.4489	.300763	0.8185	0.8750	$\bar{1}$.82607	1492.537	2.1049	.35257
.68	.4624	.314432	0.8246	0.8794	$\bar{1}$.83251	1470.588	2.1363	.36317
.69	.4761	.328509	0.8307	0.8837	$\bar{1}$.83885	1449.275	2.1677	.37393
.70	.4900	.343000	0.8367	0.8879	$\bar{1}$.84510	1428.571	2.1991	.38485
.71	.5041	.357911	0.8426	0.8921	$\bar{1}$.85126	1408.451	2.2305	.39592
.72	.5184	.373248	0.8485	0.8963	$\bar{1}$.85733	1388.889	2.2620	.40715
.73	.5329	.389017	0.8544	0.9004	$\bar{1}$.86332	1369.863	2.2934	.41854
.74	.5476	.405224	0.8602	0.9045	$\bar{1}$.86923	1351.351	2.3248	.43008
.75	.5625	.421875	0.8660	0.9086	$\bar{1}$.87506	1333.333	2.3562	.44179
.76	.5776	.438976	0.8718	0.9126	$\bar{1}$.88081	1315.790	2.3876	.45365
.77	.5929	.456533	0.8775	0.9166	$\bar{1}$.88649	1298.701	2.4190	.46566
.78	.6084	.474552	0.8832	0.9205	$\bar{1}$.89209	1282.051	2.4504	.47784
.79	.6241	.493039	0.8888	0.9244	$\bar{1}$.89763	1265.823	2.4819	.49017
.80	.6400	.512000	0.8944	0.9283	$\bar{1}$.90309	1250.000	2.5133	.50266
.81	.6561	.531441	0.9000	0.9322	$\bar{1}$.90849	1234.568	2.5447	.51530
.82	.6724	.551368	0.9055	0.9360	$\bar{1}$.91381	1219.512	2.5761	.52810
.83	.6889	.571787	0.9110	0.9398	$\bar{1}$.91908	1204.819	2.6075	.54106
.84	.7056	.592704	0.9165	0.9435	$\bar{1}$.92428	1190.476	2.6389	.55418
.85	.7225	.614125	0.9220	0.9473	$\bar{1}$.92942	1176.471	2.6704	.56745
.86	.7396	.636056	0.9274	0.9510	$\bar{1}$.93450	1162.791	2.7018	.58088
.87	.7569	.658503	0.9327	0.9546	$\bar{1}$.93952	1149.425	2.7332	.59447
.88	.7744	.681472	0.9381	0.9583	$\bar{1}$.94448	1136.364	2.7646	.60821
.89	.7921	.704969	0.9434	0.9619	$\bar{1}$.94939	1123.596	2.7960	.62211
.90	.8100	.729000	0.9487	0.9655	$\bar{1}$.95424	1111.111	2.8274	.63617
.91	.8281	.753571	0.9539	0.9691	$\bar{1}$.95904	1098.901	2.8589	.65039
.92	.8464	.778688	0.9592	0.9726	$\bar{1}$.96379	1086.957	2.8903	.66476
.93	.8649	.804357	0.9644	0.9761	$\bar{1}$.96848	1075.269	2.9217	.67929
.94	.8836	.830584	0.9695	0.9796	$\bar{1}$.97313	1063.830	2.9531	.69398
.95	.9025	.857375	0.9747	0.9830	$\bar{1}$.97772	1052.632	2.9845	.70882
.96	.9216	.884736	0.9798	0.9865	$\bar{1}$.98227	1041.667	3.0159	.72382
.97	.9409	.912673	0.9849	0.9899	$\bar{1}$.98677	1030.928	3.0473	.73898
.98	.9604	.941192	0.9899	0.9933	$\bar{1}$.99123	1020.408	3.0788	.75430
.99	.9801	.970299	0.9950	0.9967	$\bar{1}$.99564	1010.101	3.1102	.76977

FUNCTIONS OF NUMBERS (Continued)

1 to 49

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84.823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74

FUNCTIONS OF NUMBERS (Continued)

50 to 99

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9492	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8.9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

FUNCTIONS OF NUMBERS (Continued)

100 to 149

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	4.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6

FUNCTIONS OF NUMBERS (Continued)

150 to 199

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5.7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7762392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6

FUNCTIONS OF NUMBERS (Continued)

200 to 249

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.88	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	10218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37325.3
219	47961	10503459	14.7986	6.0277	2.34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6.0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48430	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4.03226	779.12	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5

FUNCTIONS OF NUMBERS (Continued)

250 to 299

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2.41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.2
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2
270	72900	19683000	16.4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.65	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.4
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4

FUNCTIONS OF NUMBERS (Continued)

300 to 349

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11526	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3

FUNCTIONS OF NUMBERS (Continued)

350 to 399

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2.55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105785
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1222.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55754	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036

FUNCTIONS OF NUMBERS (Continued)

400 to 449

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256.6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284.9	131382
410	168100	68921000	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20.3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72511713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38663	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2.62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7.5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20.6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31481	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20.8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2.28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2.26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
444	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

450 to 499

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21729	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2.66087	2.18341	1438.8	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11416	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10970	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.2	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.5	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2.68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7.8730	2.68842	2.04918	1533.1	187038
489	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2.02429	1551.9	191665
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2.69810	2.00401	1567.7	195565

500 to 549

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97628	1589.6	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	203482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1.93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1.92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8.0517	2.71767	1.91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2.72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22.9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1.88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419437	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73078	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	2.73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720

FUNCTIONS OF NUMBERS (Continued)

550 to 599

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2.74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23.6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8.2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.8	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.6	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70648	1841.0	269703
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.2	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802

FUNCTIONS OF NUMBERS (Continued)

600 to 649

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1906.9	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8.5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.6	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.3	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8.5952	2.80277	1.57480	1994.9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2.80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2 81224	1.54083	2038.9	330810

FUNCTIONS OF NUMBERS (Continued)

650 to 699

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter	
							Circum.	Area
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060.9	337985
657	431649	283593393	25.6320	8.6934	2.81757	1.52207	2064.0	339016
658	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341084
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25.7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82082	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47710	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.8	367453
685	469225	321419125	26.1725	8.8152	2.83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	328509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2.84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.5	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381553
698	487204	340068392	26.4197	8.8706	2.84386	1.43266	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746

700 to 749

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	384845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8.8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42045	2211.7	389256
705	497025	350402625	26.5518	8.9001	2.84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8.9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.2	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26.6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40252	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	519841	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409415
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2.85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.6	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302.8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424293
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425447
737	543169	400315553	27.1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27.3679	9.0816	2.87448	1.33511	2353.1	440609

750 to 799

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2.87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462041
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88649	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9.2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	500145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399

FUNCTIONS OF NUMBERS (Continued)

800 to 849

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	Area
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	511490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19190	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116

FUNCTIONS OF NUMBERS (Continued)

850 to 899

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727609	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1.14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9.5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9.5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29.7993	9.6118	2.94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9.6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

FUNCTIONS OF NUMBERS (Continued)

900 to 949

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833.7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2868.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9.7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2.97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2981.4	707330

FUNCTIONS OF NUMBERS (Continued)

950 to 999

No.	Square	Cube	Square Root	Cube Root	Logarithm	1000 × Reciprocal	No. = Diameter Circum.	No. = Diameter Area
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997.1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1.04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3025.4	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2.98453	1.03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1288	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2.98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1.01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769769
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00806	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2.99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828

INDEX

FOR GENERAL AND DATA SECTION ONLY

Note: Any product group Catalog Sections included herein are indexed separately as follows:

Oil Country Tubular Goods......P56
Mechanical Tubing.............M46
Pressure Tubes.................B40
Stainless Steel Products............S
Steel and Wire Products..........W

A

Acid brittleness, defined............D2
Acid lining, defined................D2
Acid steel, defined.................D2
Aging...........................D2
Air hardening steel, defined.........D3
AISI Steels, composition of.....D41-46
Alloy, definition of................D3
Alloys, density of.............D32-34
Alloy elements, defined............D3
effects in steel......D18
Alpha iron....................D19-27
Aluminum, effects in steel..........D18
Amorphous, defined................D3
Annealing, definition........D3-4, G29
Antimony, physical constants......D28
Areas and circumferences of circles...................D178-182
Areas of circular segments...D183-185
Arcs for unit radius, length of circular....................D188
Area, percentage reduction of...D70-71
Area, steel bars...............D74-75
Atmospheric pressure.............D90
Atomic weights...............D28-31
Austenite, constitution.........D19-27
grain sizes..........D47-48

B

Babbitt metal, density.............D35
Banded structure, definition.........D4
Bark, definition...................D4
Bars, weights and areas of steel.D74-75
Basic lining, definition.............D4
Basic steel, definition...............D5
Beams, properties of solid and tubular...............D105-125
Beryllium, physical constants......D28
Bessemer process, definition........D5
Beta Iron.....................D19-27
Billet, definition...................D5
piercing..................G20
Bismuth, physical constants........D28
Black annealing...................D5
Blast furnace, definition.......D5, G4-5
Blister, definition..................D5
Blister bar, definition..............D5
Bloom, definition..................D5
Blooming mill, definition...........D5
Blowhole, definition...............D6
Blue annealing, definition..........D6
Blue brittleness, definition..........D6
Box annealing, definition...........D6
Brass, density....................D36
Bright annealing, defined...........D6
Brinell hardness, numbers.........D68
conversion.......D69
Bronze, density..................D36
Burning..........................D6

C

Capped steel..................D6, G13
Carbon-Iron, constitution.......D20-27
diagram............D19
Carbon free, definition..............D6
Carbon steel, definition.............D6
specifications........D41
weight of bars....D74-75
Carbonization, definition...........D6
Carburizing, definition.............D6
Case definition....................D6
Case hardening, definition..........D6
Cast iron, density.................D37
Cast steel, definition................D6
density................D33
Casting strains, definition...........D7
Cementite....................D20-27
Centigrade, conversion to fahrenheit.....................D89
Chemical analyses, steel........D41-46
Chemical elements, density.....D35-40
physical constants........D28-31
Chill cast pig, defined..............D7
Chipping, defined.................D7
Chromium, effect of...............D18
Circles, areas and circumferences.....D178-182
properties of..........D177
segments of.......D186-187
Cleavage plane, defined............D7
Cobalt, effect in steel..............D18
Coefficient of linear expansion, tables.....................D86-87
Cogging, definition................D7
Cold drawn tubing............G33-35
Cold shut, definition...............D7
Cold working, defined.............D7
Columbian, effect in steel..........D18
Columns and sections........D128-131
Combined carbon, definition........D7
Comparison of physical properties..................D49-66

Composite steels, definition.........D7
Composition of steels, chemical D41-46
Constitution, iron-carbon alloys D20-27
diagram.............D19
Conversion tables
energy, volume, weight..........D79
equivalents of measure.......D82-85
hardness.......................D69
load...........................D72
metric....................D94-104
temperature F.°, C.°..........D88-89
weights and measures........D80-81
Copper, alloys, density............D36
effects in steel.....D18
Core, definition...................D7
Cored structure, definition..........D7
Critical: points, range, temperature
in iron-carbon alloys.........D19-27
Crop, definition...................D8
Cup fracture, definition.............D8
Cupping, definition.................D8
Cyaniding, definition...............D8

D

Decalescence, definition............D8
Decarburization, definition..........D8
Decimal equivalents of
inch & foot...................D132
Decimal equivalents of B.W.G.
and Fractions.................D133
Definitions, steel terms..........D2-17
Dendrite, definition................D8
Density of alloys...............D32-34
Deseaming, definition..............D8
Differential heating, definition.......D8
Dissolved carbon, definition........D8
Divorced cementite, definition.......D8

E

Elements, physical constants....D28-31
Elongation, defined................D8
Elongator process................G23
Endurance, limit...................D8
ratio..................D8
Equilibrium.....................D21
Equivalents of measure.........D82-85
Eutectic alloy, definition............D9
Eutectoid steel, defined.............D9
Exfoliation, definition..............D9
Expansion, coefficient of linear .D86-87

F

Fahrenheit, conversion to
centigrade.....................D88
Fatigue, defined...................D9
Ferrite, defined...............D9, D20
Ferroalloy, definition...............D9
Fiber, definition...................D9
Fiber stress, definition..............D9
Finished steel, definition............D9
Finishing temperature, defined......D9
Flakes, definition..................D9
Flash, definition...................D9
Forging strains, defined...........D10
Formulas, trigonometric..........D190
Fracture, definition................D10
Fracture test,defined...............D9
Free Ferrite, definition............D10
Freezing points, physical
constants...................D28-31
Fusible alloys, defined............D10
Functions of numbers........D215-236
Functions, trigonometric,
natural..................D191-196
Functions of steel making elements.D18

G

Gamma iron, definition............D10
Gauges, wire, comparison of.......D67
Ghost, lines, ferrite, defined.......D10
Glossary of terms..............D2-17
Gold, gravity and weight..........D37
Grains, definition................D10
Grain growth, defined............D10
Grain sizes, Austenite..........D47-48
Granular pearlite, definition.......D10
Granulation, definition...........D10
Gravities, specific.............D35-40
Gyration, radius of..........D160-165

H

Hardening, definition............D10
Hardness, Brinell................D68
Hardness, conversion numbers.....D69
Heat contents....................D34
Heat tinting.....................D10
Heat treating, definition of.........D10
Hot shortness....................D11
Hot working.....................D11
Hypereutectoid, definition of.......D11
Hypoeutectoid, definition of.......D11

I

Inches, conversion tables D94-101, 132
Inclusions, definition.............D11
Index,
Oil Country Catalog.............P56
Mechanical Tubing Catalog.....M46
Pressure Tube Catalog...........B40
Stainless Steel Products............S
Steel and Wire Products...........W
Inertia, moment of..........D148-153
Ingot, definition.................D11
pouring................G10-14
soaking................G15-18
Ingot iron, definition.............D11
Interconversion tables,
equivalent measures..........D82-85
load..........................D72

Interconversion tables—Continued
metric....................D94-104
temperature °F., °C..........D88-89
units of energy, volume, weight..D79
weights and measures........D80-81
Iron, atomic weight and number...D28
specific gravity...........D37-38
constitution.............D19-27
Iron, carbon-alloys, see steel

K

Killed steel, definition........D11, G13

L

Lap, definition....................D11
Lap weld, definition...............D11
Lead, specific gravities............D38
Ledeburite, definition..............D11
Liquidus, defined...................D11
Load conversion table.............D72
Logarithms of numbers......D197-214
Lüder's lines, defined..............D11
Lute, definition....................D12

M

Macroscopic, definition............D12
Macrostructure, definition.........D12
Magnesium, specific gravities......D38
Martensite, definition..............D12
Matrix, definition..................D12
McQuaid-Ehn test..............D47-48
Measure, equivalents of.........D80-85
Mechanical, properties, defined....D12
testing.....D12
working...D12
Metric conversion tables......D94-104
Metalloid, definition..............D12
Modulus of elasticity.............D13
Modulus, section of.........D154-159
Monel metal, specific gravity.......D38
Muntz metal, see copper alloys

N

Network structure, definition......D13
Neumann bands, definition........D13
Numbers, functions of.......D215-236
natural trigonometric..........D191-196
Brinell hardness......D68-69
Nickel, density....................D38
Nitriding, definition..............D13
Normalizing, defined.........D13, G28

O

Overheating.......................D13
Oxygen, specific gravity...........D39

P

Patenting.........................D13
Pearlite, defined..................D13
in iron-carbon alloys.....D23
Percentage reduction of area....D70-71
Permanent mold, definition........D13
Permanent set, definition..........D13
Phosphorus banding...............D13
Physical constants.............D28-31
Physical constants of elements..D28-31
Physical properties,
AISI Curves.........D49-66
chemical elements....D28-40
definition...............D13
Physical testing, defined...........D13
Pi, values for the combination....D189
Piercing, definition................D14
billets................G20-21
Pig iron, defined..................D14
Pilger process................G24-27
Pine tree crystals..................D14
Pipe, definition...................D14
Pit...............................D14
Pittsburgh Products................G3
Plane figures, mensuration of.....D173
Pot annealing.....................D14
Pouring...........................D14
Properties, chemical, of steel ...D41-46
of the circle..........D177
physical, of steel....D47-66
of seamless steel tubing.........D142-147
of sections.......D166-172
of tubular and solid beams.........D105-125

Q

Quartenary alloys, definition.......D14
Quenching, definition.............D14

R

Radius, arcs for unit.............D188
Radius of gyration...........D160-165
Recalescence, definition...........D14
Red brass, specific gravity.........D36
Red shortness, definition..........D14
Reduction of area, definition.......D14
percentage ..D70-71
Reeling..........................G30
Refining temperature..............D14
Regenerative quenching, definition.D14
Rimmed steel, defined........D14, G11
Riser, defined....................D15
Rockwell hardness, conversion....D69
Rolling......................G22-28

S

S.A.E. steels, composition......D41-46
Scab, definition..................D15
Scarfing.........................D15
Scleroscope hardness, conversion..D69
Seam, definition..................D15
Section modulus............D154-159

Secondary hardening, defined......D15
Segments of the circle........D186-187
Selenium, physical constants.......D30
Self-hardening steel, definition.....D15
Shafting, solid and hollow......D76-78
Shortness.........................D15
Silicon, physical constants.........D30
Silky fracture, definition...........D15
Sinkhead or hot top...............D15
Sinking and sizing................G31
Skelp, definition..................D15
Slabbing mill, definition...........D15
Slip bands, definition..............D15
Soaking, definition................D15
Solidification range...............D16
Solidus line, definition............D16
Sonims, definition.................D16
Sorbite, definition.................D16
Spalling, definition................D16
Specific gravities..............D35-40
Specific heat, physical constants....D34
Specifications, alloy and carbon
steels........................D41-46
Spheroidal cementite, definition....D16
Spiegeleisen, definition............D16
Stead's brittleness.................D16
Steel, alloying elements in.........D18
heat treatment of.........D49-66
grain sizes..............D47-48
iron-carbon diagram......D19-27
manufacture of...........G4-19
specifications AISI, SAE
and NE...............D41-46
terms and definitions......D2-17
Surfaces and volumes
of solids..................D174-176

T

Tables
areas and circumferences
of circles................D178-182
arcs for unit radius.............D188
Brinell hardness numbers........D68
coefficients of linear
expansion................D86-87
columns..................D128-131
decimal equivalents of an inch..D132
density of alloys.............D32-34
energy—volume—weight........D79
equivalents of measure.......D82-85
functions of numbers......D215-236
gauges..................D67, D133
hardness conversion............D69
heat content...................D34
inertia, moment of.........D148-153
load conversion................D72
logarithms of numbers.....D197-214
mensuration of plane figures....D173
metric conversion..........D94-104
metric system...............D91-93
percentage reduction of area..D70-71
Tables—Continued
physical constants of elements D28-31
pounds and tons, conversion.....D73
properties of the circle.........D177
radius of gyration.........D160-165
section modulus...........D154-159
segments of the circle......D186-187
solid and hollow shafting....D76-78
specific gravities and weights.D35-40
surfaces and volumes
of solids...............D174-176
temperature conversion.......D88-89
trigonometric formulas.........D190
trigonometric, functions...D191-196
tubing, sectional area of....D142-147
values for the combination of Pi.D189
weights and areas of bars.....D74-75
weights and measures........D80-85
weights of steel tubing.....D134-141
Tapping, definition................D16
Teeming..........................D16
Temper carbon, definition.........D16
Temperature, conversion.......D88-89
Tensile properties.............D49-66
Terms, glossary of.............D2-17
Ternary alloy.....................D16
Testing, Brinell..................D67
conversion numbers......D69
load conversion..........D72
Tin alloys, specific gravity.........D40
Torsion....................D126-127
Trigonometric formulas..........D190
Trigonometric functions.....D191-196
Troosite, defined..................D16
Tubes, manufacture of.........G20-30
Tubular and solid beams,
properties of.............D105-125
Tungsten, effects of...............D18
Twin bands, definition............D17
Twin crystals, definition...........D17

V

Values for combination of Pi.....D189
Vanadium, effects in steel..........D18
Volume of solids............D174-176
Vickers hardness, conversion......D69

W

Weights, and areas of steel bars D74-75
seamless tubing....D134-141
and measures.........D80-85
and specific gravities..D35-40
Widmanstatten structure...........D17
Wire gauges, comparison..........D67
Wire rod, definition...............D17
Woody fracture...................D17
Work hardness, definition.........D17

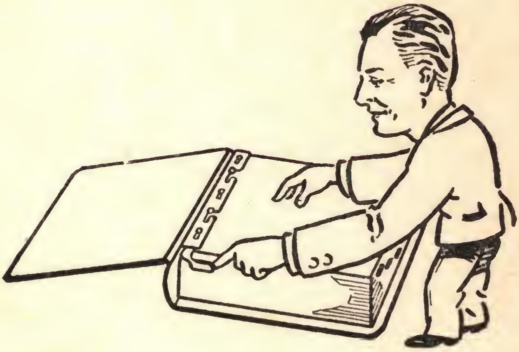
Y

Yield point, definition.............D17
Yield strength, definition..........D17

Z

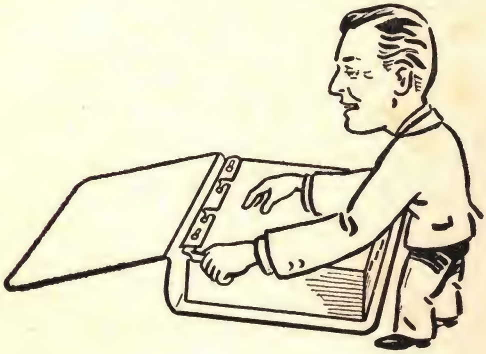
Zinc, specific gravity.............D40

Instructions



To Remove or Change Sheets

Turn to page where change is to be made. Remove all sheets above this page with the bar attachment for holding the sheets.



THE HEINN COMPANY
MILWAUKEE, WISCONSIN, U. S. A.
ORIGINATORS OF THE LOOSE-LEA

102
102
204
1020
104

107
107
749
1070
11449

109
106
636
1060
1123

PAT'D. MAY 26-25
Manufactured and Sold by
THE HEINN COMPANY
MILWAUKEE, U.S.A.
PATENT NO. 1775121
1801256

2678-43